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SOUTHWEST FISHERIES CENTER

HONOLULU, HI 96812

P.O. BOX 3830

September 1983

HONOLULU LABORATORY

NOV 1 1983

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

NATIONAL MARINE FISHERIES SERVICE

A FISHERY DATA COLLECTION SYSTEM: GUAM

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A FISHERY DATA
COLLECTION SYSTEM:
GUAM

FINAL REPORT

Prepared for:

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September 1983



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INTRODUCTION

Over the past 20 years, Guam's fisheries have experienced increasingly significant fishing pressure from recreational, subsistence, and commercial activity, as well as destructive illegal fishing practices. In an attempt to quantify this fishing pressure, the Department of Aquatic and Wildlife Resources (DAWR) has been monitoring the Island's fishing activities. An integral part of this monitoring effort has been the collection of fishing data. In hopes of identifying trends in fishing participation, effort, and catch, the DAWR has sponsored a wide variety of data collection methods over the past 20 years. Even though these data collection efforts have resulted in a fairly substantial data set, the reliability of the total data set has been questioned, because of frequent personnel changes and poorly documented sampling procedures. Hence, without the necessary documentation, the evaluation of fishing data cannot be properly accomplished. Fortunately, since 1977 significant progress has been made by the DAWR to rectify the shortcomings surrounding its fishery data collection operation. Currently, the DAWR's data gathering operation lacks the formal design and documentation necessary for ensuring a useful Fishery Data Collection System (FDCS) in the future.

A Fishery Data Collection System is a set of procedures, methods, and principles which direct the collection process of fishing data. Specifically, the major elements of the FDCCS are as follows:

- Detailed description of FDCCS objectives
- Specification of the general design components for the FDCCS
- The required sampling designs
- Sampling activity procedures
- Processing methods for the system's data base
- Expansion algorithms and their reliability
- Quality assurance methods
- Presentation of FDCCS data and results

The purpose of this study is to provide the framework for such a FDCCS. This project has two major tasks: first, the study will analyze the present information-gathering system and survey techniques. Second, the study will design a statistically reliable data collection system to provide and process the needed information on a continuous basis. Where appropriate, the existing survey structure will be utilized in the FDCCS.

The body of this report is divided into two sections. Section I contains a general description of the current fishery data collection system. Contained in this section is a brief historical background of DAWR's data collection efforts. The current system is then reviewed in some detail. This review

considers separately the two primary fishing surveys, i.e., the inshore survey and offshore survey. An overall assessment of the current system concludes this section of the report.

Section II presents the proposed FDCS. Each of the eight elements (identified above) of the system are presented and discussed. The sampling design and the expansion algorithm elements comprise the major efforts of this project. Specifically, the sampling design element explains the proposed statistical sampling techniques and provides the estimates of the manhour and dollar resources required to implement the system. The expansion algorithm element presents the methodology for arriving at the numerical estimate for the total Island-wide catch as well as specifying the reliability of this estimate. Both these elements are presented in detail for use in the FDCS. The remaining six elements are discussed only in terms of their relationship to the sampling design and expansion of algorithm elements.

Throughout this report, possible alternatives or strategies for the FDCS will be discussed and assessed. The most feasible solution will always be identified.



SECTION I

GENERAL DESCRIPTION OF THE CURRENT FISHERY DATA COLLECTION SYSTEM

INTRODUCTION

The first step in designing a sampling program is to review and study past efforts. Valuable insight from such a study will assist in avoiding previous sampling pitfalls and identify worthwhile procedures. At the present time, the DAWR is the primary source of fishery information for Guam.

BRIEF HISTORICAL BACKGROUND OF DATA COLLECTION EFFORTS

Fishery data collection efforts on Guam were initiated by the DAWR in the mid-1960's, primarily through the use of creel survey techniques and aerial surveying. Since that time, a number of survey methods and a variety of procedural changes have occurred. Nevertheless, some level of sampling effort has been maintained to the present time. From the outset of these early sampling efforts, the DAWR has attempted to quantify the Island's fishing activity in terms of catch, effort, and participation information.

Due to a lack of procedural documentation, insufficient sampling levels or structure, and missing data, a significant portion of the data collected over the past 20 years cannot be

included in the Island's fishery data base (data collected prior to 1970).

In addition, the Western Pacific Regional Management Council recently funded a study by the Pacific Basin Environmental Consultants to study Guam's fisheries data for the period of 1970 to 1980. This report provides a detailed description of all fishery data collected during this period. The report shows approximately 80 percent of the data collected by the DAWR during this 10-year period was collected from 1977 to 1980. Due to the amount and quality of the data collected since 1977, coupled with the lack of sampling documentation prior to 1977, the DAWR believes that all years prior to 1977 should be omitted from the data base as well. Thus, for analytical purposes, the available data base includes information collected from 1977 to the present.

Aerial Survey

The aerial fisheries survey effort was initiated in mid-1960. This roughly instantaneous assessment of fishing activity (the flights averaged 1½ hours in duration) was implemented during nine of the 17 years, during the period of 1963-1979, with a total of 169 flights. These flights were divided more or less equally between weekend/holiday days (WE/H) and weekdays (WD). The basis for the division of sampling effort between WE/H and WD originates from the significantly different fishing activity which normally occurs on the Island between

these two periods. This temporal distinction is carried over to the creel survey efforts as well.

All in all, the aerial surveys were a valuable activity. These surveys provided participation data, i.e., number of fishermen by fishing method for the entire Island. Only an aerial survey can provide this type of information. This type of Island-wide information will greatly assist in the assigning of proportional weights to areas which are not now surveyed due to geographical or other constraints.

Data from the aerial fisheries survey were compiled for geographical areas (Figure 1) that would allow comparison with data collected within inshore creel census regions. Under the current survey program, DAWR has divided the creel survey area into three regions. Figure 1 shows the location of these regions, as well as the non-creel survey areas. As mentioned above, the aerial survey's purpose was to measure fishing participation. During the conduct of the aerial survey, once a fisherman was sighted, the survey area was noted, along with the fishing method used. Interestingly, during the nine survey years between 1963 and 1979, only two percent of the fishing methods were determined to be unidentifiable. Table 1 presents the percent of fisherman using one of the four principal fishing gears.

The data in Table 1 show combined gill and surround netting to be the most popular fishing method. The remaining

Figure 1

INSHORE FISHING SURVEY REGIONS

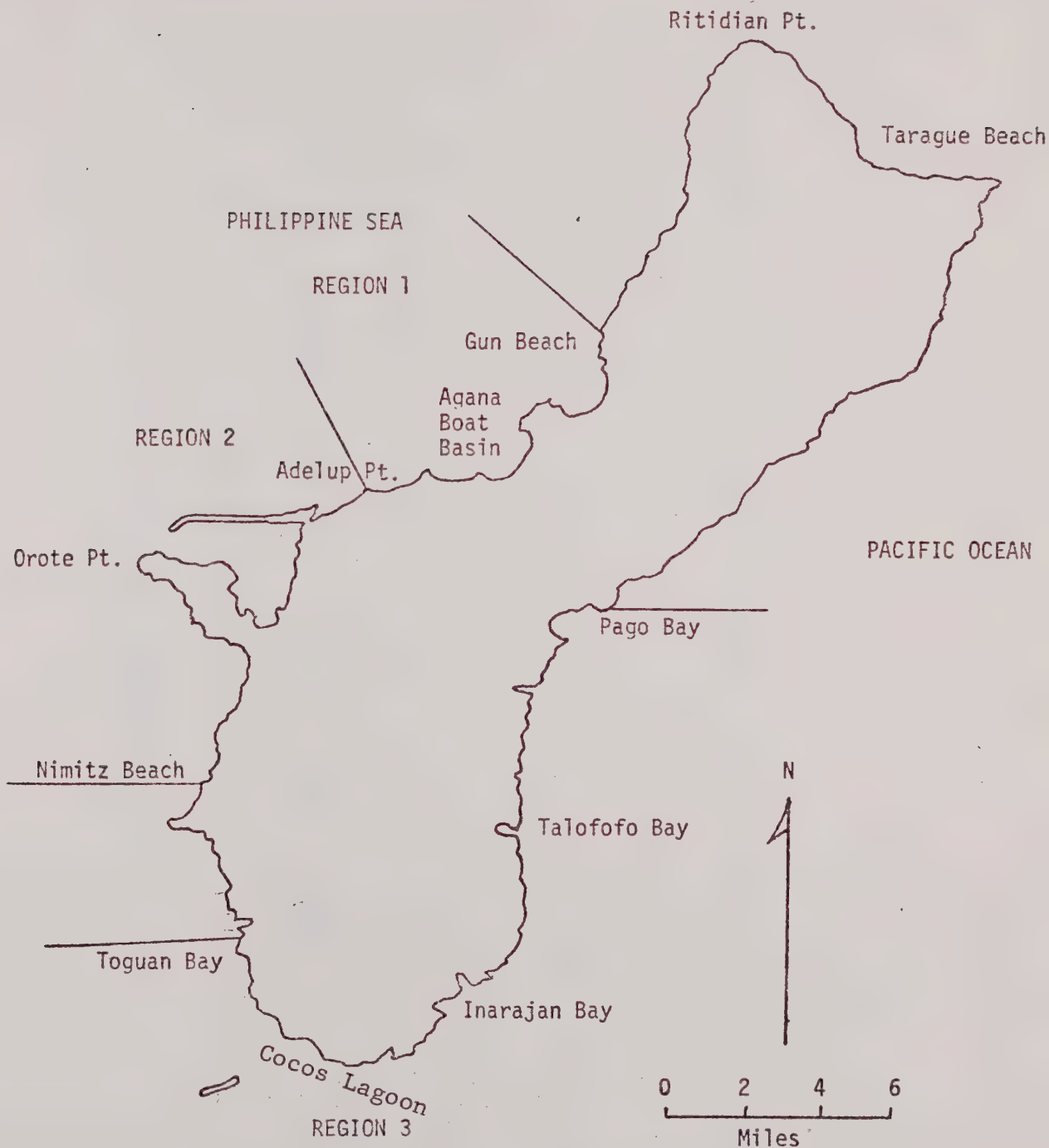


Figure 1. The Island of Guam. The Inshore Fishing Survey Regions are as follows: Region #1 - Gun Beach to Adelup Point
Region #2 - Adelup Point to Nimitz Beach
Region #3 - Pago Bay to Toguan Bay

Table 1

AERIAL FISHERIES SURVEY:
PERCENT OF FISHERMEN USING GIVEN GEAR

Fishing Gear	Percent of Fishermen					
	Percent Using Method	In Non- Creel Region	In Creel Region	In Creel Region 1	In Creel Region 2	In Creel Region 3
Hook and Line	19.5%	6.9%	93.1%	32.0%	34.2%	26.9%
Cast Netting	17.6	20.4	79.7	24.2	25.9	29.6
Gill and Surround Netting	38.1	9.9	90.1	39.8	17.9	32.4
Spearfishing	17.9	20.0	80.0	24.2	32.9	22.9
Other*	6.9	22.8	77.2	--	--	--

*"Other" category includes octopus hunting, clamming, shelling, and unidentified.

Source: DAWR
CIC Research, Inc.

three identified fishing methods are relatively equal. A close look at the last three aerial survey years (1976, 1978, 1979) reveals that the relationship between the four major inshore methods remains relatively stable except for a marked decline in spearing participation in the 1979 survey (9.4%).

Offshore Survey

While the aerial survey dealt primarily with the inshore fishery, the creel survey efforts from 1977 to 1981 focused on both the inshore and offshore fisheries. Offshore fishing requires the use of a boat and the fishing activity is concentrated beyond the reef area. The three principal offshore fishing methods are trolling, bottom fishing, and spearfishing.

Past offshore surveys, 1977 to 1981, have been directed at obtaining not only participation data, but catch and effort information as well. Basically, the information collected during these years includes number, weight and length of fish caught, species identification, hours fished, weather data, fishing location, gear type, and number of fishermen. The consistency and quality of this information has varied throughout the years with the more recent years producing the better data set.

Sampling effort has been directed at the principal boat basins, i.e., the Agana and Merizo boat basins. Other possible offshore launch areas, such as the Apra Harbor, have only been obtained sporadically during this five-year period. Offshore sampling effort was two days per month in 1977 and grew to

six days per month by 1981. During 1981 the Agana Boat basin was sampled on an average of four days per month, while Merizo was sampled twice a month. Since 1977, total sampling effort has changed dramatically from a low of 11 total sampling days in 1977 to a high of 69 days in 1980. An average of 44 sampling days per year were expended during the five-year period.

The sampling effort was more or less equally divided between WE/H and WD.* Hence, the expansion method employed to arrive at catch estimates separates the sample catch figures with respect to WE/H and WD. Sampling days were randomly selected by a lottery method, although personnel and funding problems over the years sporadically resulted in rescheduling census days to maximize data collection. In addition, over the course of this five-year period, the actual surveying was shifted more and more towards the later afternoon and evening hours, since this time period saw the greatest activity at the boat basins.

By far the most frequent method of offshore fishing is trolling. Table 2 summarizes the results of the offshore sampling effort by fishing method from 1977 to 1981. Interestingly, during the latter years, the participation levels among the different fishing methods stabilized. Also, since 1979 the sample effort for this survey has greatly increased.

*It is interesting to note that the origin for equally dividing sampling effort in this fashion was based on aerial surveys conducted in the early 1960's. However, there is no doubt that significantly different fishing activity occurs between these two periods.

Table 2

OFFSHORE FISHING: PERCENT OF BOATS USING FISHING GEAR

1977 to 1981

	<u>Percent of Boats Using Fishing Gear</u>					
<u>Fishing Gear</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>Avg.</u>
Trolling	81.2%	78.9%	87.4%	78.7%	78.4%	80.9%
Bottom Fishing	9.4	13.2	9.1	15.6	17.7	13.0
Spearfishing	9.4	8.0	3.5	5.7	4.0	6.3
Total Days Surveyed	11	33	57	69	52	44

Source: CIC Research, Inc., 1983.
DAWR

Inshore Survey

The inshore creel survey has been the major focus of the DAWR. Like the offshore survey, the inshore survey collected a similar set of information, i.e., catch, effort, and participation data, along with other pertinent information. In the case of the inshore fishery, the fishing activity occurs in or near the reef area, with the primary fishing methods being hook and line, cast netting, gill netting, surround netting, and spearfishing. In 1978 an attempt was made to sample each region twice a month, once on a WD and once on a WE/H. In addition, no two regions were sampled on the same day due to personnel and time constraints. Thus, under this design a total sampling effort of six days per month was expended on the inshore survey. On a given sampling day within a region, the goal was to obtain as many interviews as possible without backtracking on the census route.

Total sampling effort has varied little over the five-year period from a low of 4.2 days/month in FY 1981 to a high of 6.0 days/month in FY 1977. An average of 65 days were sampled per year. Sampling days were selected at random with sampling effort again divided equally between WE/H and WD.

An entire day was sometimes necessary to adequately sample a region. Interestingly, a look at the information collected over this period exhibits a fair degree of consistency. Table 3 shows the percent of fishermen using a given fishing method during

Table 3

INSHORE FISHING: PERCENT OF FISHERMEN USING A GIVEN GEAR

FY 1977 - 1981

Fishing Gear	Percent of Fishermen Fishing				
	1977	1978	1979	1980	1981
Hook and Line	21.9%	30.9%	42.4%	45.1%	46.2%
Cast Netting	21.2	14.3	12.0%	16.4%	19.4%
Gill Netting	52.8	29.9	20.2	19.5	16.3
Surround Netting		12.8	16.4	13.5	12.3
Spearfishing	4.2	12.1	9.1	5.5	5.8
Total Sampling Days	36	68	87	68	51
No. of Months	6	12	15	12	12
					65*

*Based on FY 1977-1981, doubling 1977 data and using the first 12 months of 1979.

Sources: DAWR
CIC Research, Inc.

fiscal years 1977 - 1981, while Table 4 presents the percent of total catch attributable to each method. Tables 3 and 4 show some interesting, but not startling, results. While the hook and line method accounts for an average of 40 percent of the participation, it accounts for only 13 percent of the catch. Surround netting is the most productive method in terms of percent of total catch.

Also of interest, is the comparison of gear-use distributions from the aerial and inshore surveys. Not suprisingly, the difference occurs between the spear and hook and line methods. In terms of the inshore survey, the spearfishing method is the most difficult to observe, while the converse is true of the hook and line method. For the aerial survey, the opposite appears to be true. All in all, the results between the surveys are compatible. Further analysis of these tables will occur in the following section.

CURRENT DATA COLLECTION SYSTEM

Before reviewing the specifics of the current fishery data collection system on Guam, a few general comments concerning the system seem appropriate. As the discussion on the system's historical background showed, for all intents and purposes, a data collection effort of sufficient quality did not commence until 1977. Since that time, sampling effort was increased and, more importantly, written documentation concerning the survey's

Table 4

INSHORE FISHING CATCH: PERCENT OF CATCH USING A GIVEN FISHING GEAR

<u>Fishing Gear</u>	<u>Percent of Catch</u>				
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>Average</u>
Hook and Line	2%	15%	14%	14%	13%
Cast Netting	54	16	9	12	20
Surround Netting		31	29	51	35
Spearfishing	2	8	19	5	9

Sources: DAWR
CIC Research, Inc., 1983

procedures and methods was maintained. A look at the past five years clearly indicates that the entire sampling program has undergone a valuable evolutionary process. This process essentially has been the result of a conscious effort by DAWR to develop a high-quality, more efficient data collection system. Today, the fundamental tenets of the sampling program are derived from the experiences of the past sampling years.

Currently, the DAWR participates in two creel surveys identified as the offshore and inshore surveys. Both these surveys are discussed in some detail on the following page. Currently, these surveys require a total of 10 sampling days, or approximately 80 manhours of effort, allocated each month to collecting the desired fishing data (60 percent to the inshore program and 40 percent to the offshore program).

Offshore Program

The fiscal 1982 report indicates two objectives for the offshore creel survey:

1. To quantify and monitor trends in fishing participation, effort, and catch which occurs outside the reef margins in boats.
2. To collect biological data from specimens examined during fishermen interviews.

In addition to the above objectives, the procedures implemented during the 1982 (FY) creel survey were designed to maximize (1) the collection of biological data and (2) the number of

completed fishermen interviews per unit time spent in the field. To these ends, the sampling procedures for 1982 took into consideration variables and methods not utilized in previous years, i.e., weather, sea state, and daily temporal trends in fishing activity. While it would be impractical to expect that a sampling program should maintain complete coverage of the entire boat-accessible coastline 24 hours a day, the program should generate a representative picture of fishing activity.

The presentation of the current offshore sampling program will focus on three areas: survey coverage, survey frequency, and sampling methods. Survey coverage deals with where the sampling takes place, while survey frequency reveals how often the sampling will be done. For FY 1982, sampling occurred at two locations: the Agana Boat Basin, located on the leeward side of the Island and the most active boat launch area on the Island, and Merizo Pier, located within Cocos Lagoon on the southern tip of Guam. Due to manpower and logistics difficulties, Merizo was sampled during only the first third of the fiscal year, for a total of six sample days. An attempt was made to obtain fishing data through telephone interviews which, not suprisingly, proved unsuccessful. Therefore, the offshore sampling program was essentially measuring the fishing activity of the Agana boat basin.

With only a few exceptions, the Agana boat basin was surveyed four times a month, twice on WD and twice on WE/H. The DAWR believes strongly that the vast majority of offshore fishing activity passes through the Agana boat basin and to a lesser extent, Merizo Pier. Generally, the sampling effort was conducted between 5:00 p.m. and 9:00 p.m. This time period was thought to coincide with the return of that day's fishing fleet. The sampler attempted to determine the number of boats returning prior to his/her arrival. This information was used in calculating a proportional factor which was to be incorporated into the estimate of daily offshore participation. Another component added to the sampling program was the adjustment for "bad" weather days. On those days when the sampler determines that the weather and/or sea conditions prohibit offshore fishing, no survey was conducted and the survey that day was rescheduled. All survey days were determined by lottery.

The above discussion of the offshore sampling program really deals with sampling methods. While no formal guidelines exist, the sampler follows a fairly well-defined sampling scheme. To record sampler findings, two survey instruments are utilized: an "Offshore Fishing Participation Census" form and an "Offshore Creel Census" form. The "Participation Census" form contains participation information (see Figure 2) including boat, number of people, gear, etc., plus a diagram of the boats moored at the boat basin. This diagram enables the sampler to quickly

Figure 2

OFFSHORE SURVEY FORM: PARTICIPATION

DIVISION OF AQUATIC & WILDLIFE RESOURCES
DEPARTMENT OF AGRICULTURE
GOVERNMENT OF GUAM

Offshore Fishing Participation Census
Agana Boat Basin

Date _____ WE/H WD

Time _____

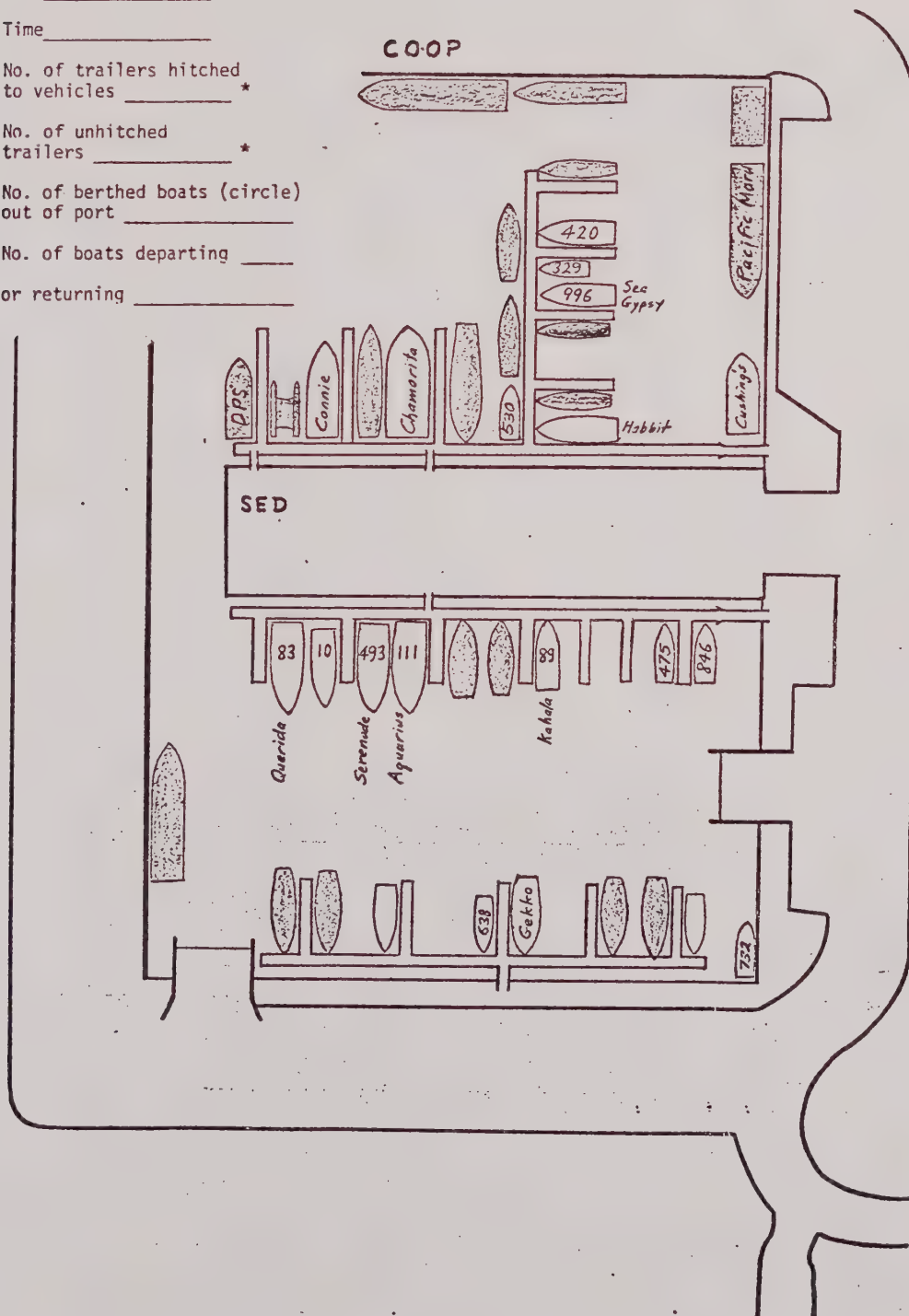
No. of trailers hitched
to vehicles _____ *

No. of unhitched
trailers _____ *

No. of berthed boats (circle)
out of port _____

No. of boats departing _____

or returning _____



* Please note location of all trailers on map above and indicate whether or not they are hitched to a vehicle.

Figure 2 (Cont'd.)

OFFSHORE SURVEY FORM: PARTICIPATION

Date _____ WE/H _____ WD _____ Interviewer _____

Boat No.	Time	Location	No. of Persons	No. of Gear Units & Method	Est. distance offshore	Direction headed or anchored	Weather & Water Conditions
-------------	------	----------	-------------------	----------------------------------	------------------------------	------------------------------------	-------------------------------

[illegible]

identify which boats are still out and to locate boat trailers for further reference that evening. This form is utilized during an inshore census day to aid in an offshore census conducted later in the day. The "Creel Census" form contains the detailed catch and effort data (see Figure 3) and is utilized during the offshore census.

During a survey, the sampler first determines the status of the boats in the basin using the diagram mentioned above. Moored boats still fishing are identified as well as the location of the boat trailers. Also, the sampler attempts to determine if any boats came in prior to his/her arrival and, if possible, interview the boats' skippers. This information assists the sampler in determining the fishing participation, i.e., number of boats for the day.

When a boat returns during the sampling period, the sampler interviews the skipper about his catch, time spent fishing, gear, location, and the other items contained in the offshore creel census questionnaire. Depending on the size of the catch, the interview can vary from a couple of minutes to half an hour; however, the average is five to 10 minutes. The sampler attempts to interview as many fishermen as possible. When multiple boats come in simultaneously, the sampler uses his/her own discretion as to which boats to sample. For the most part, the sampler is able to position himself/herself in such a way as to observe all the activity at the boat basin.

OFFSHORE SURVEY FORM: CATCH/EFFORT
DIVISION OF AQUATIC & WILDLIFE RESOURCES
DEPARTMENT OF AGRICULTURE
GOVERNMENT OF GUAM

Interview # _____
Interviewer _____
Interview time _____

OFFSHORE CREEL CENSUS

on _____		Q= _____		Date _____	WD _____	WE _____
:	No.	hrs. in	No. fishermen		FAD buoy used	
	lines	use	Start time		Where	
rolling	_____	_____	Lost time	_____	When	_____
ottom fish	_____	_____	Stop time	_____	No. passes	_____
peargun snorkel	_____	_____	Time most fish	_____	Catch:	_____
peargun scuba	_____	_____	caught	_____		_____
ther	_____	_____				
g _____	Boat # _____		Bait _____			

TYPE DATA: 1 3 1 2 3

[illegible]

TYPE DATA	1 ACT	2 CALC	3 EST
L NO. FISH			
L WT. (kg)			
L NO. SPP.			

Meteorological Data

Wind dir. _____ Weather _____
-22- Wind speed _____ Cloud cover _____
Lunar day _____

An essential element of the offshore program is the expansion method employed to derive the offshore estimates. Currently, the procedures involve a number of linear approximations. For example, the catch estimate is currently adjusted for weather conditions because the expansion method proportionately accounts for bad weather days, i.e., no fishing, as well as low participation days. Since sampling is now restricted to the Agana Boat Basin only, Island-wide estimates are computed through a series of proportional weights taking into consideration fishing activity in non-surveyed areas. Separate estimates are calculated for trolling, bottom fishing, and spearfishing -- the three major offshore fishing methods. For FY 1982, monthly catch estimates for Agana boat basin were computed.

Inshore Program

For fiscal year 1983, the name "inshore sampling program" is somewhat of a misnomer. The DAWR has redesigned the program to essentially estimate participation for both inshore and offshore fishing activity. For example, in the case of offshore activity, the survey furnishes superior participation estimates when compared to the offshore sampling program because the coverage as well as sampling frequency is so much greater. In order to implement this new focus of the inshore program, the collection of catch/effort data has to be de-emphasized. The collection of catch/effort data is now limited to three days/month

(one day per survey region). Catch/effort data is compiled for as many completed or as nearly completed fishing trips as possible within a maximum of six hours per day.

The inshore program will be discussed in terms of its sampling coverage, frequency, and methods. Combined, the three inshore regions encompass 60 percent of the total Island coastline. More importantly, according to the DAWR, 80 to 90 percent of the Island-wide fishing activity occurs within the three regions. Originally, the inshore program sampled each region on separate days. Now, the inshore survey covers the entire three-region area in one sampling day. While there is little doubt that fishing activity exists in the non-surveyed areas, the expenditures required to adequately estimate this effort would far outweigh the benefits of the additional information.

The inshore program is conducted on six days each month -- again evenly split between WD and WE/H. A sampling day begins either at Gun Beach on the northern tip of Region 1, or at Pago Bay on the opposite side of the Island in Region 3 (refer to Figure 1). The selection of a starting point is determined randomly each sample day. Once the starting point has been selected, the sampler drives around the Island through each region in sequence. The sampling day begins at 9:00 a.m. and runs from six to eight hours, depending on the number of catch/effort questionnaires administered. The driving is difficult in the sense that it requires an expert knowledge of the island's geographical and road layout. The coastline can be observed clearly from

a number of vantage points which are discoverable if one knows the correct road or turn to take.

The sampler carries a sufficient supply of the three questionnaires: the inshore participation questionnaire, the off-shore questionnaire, and the inshore catch/effort questionnaire (see Figures 3, 4, & 5). In addition to these questionnaires, the sampler carries a code book, measuring instrument and, most importantly, a pair of binoculars. Because the sampler's objective is to observe and identify fishing activity along the Island's coastline, he or she must be able to observe as much of the coastline as possible. Because most of the fishing activity is dispersed along the reef, the only way to observe the fishing activity is through the use of binoculars. At times the sampler's observations are being made from a distance of a mile or more. The need for a powerful set of binoculars is critical to the success of the inshore survey effort. At each stop the sampler observes the fishing activity and attempts to identify the fishing method, number of people, location, etc. Often it takes a trained eye to spot the fishing activity and, in addition, determine the gear. The sampler must judge whether or not to administer a catch/effort questionnaire. If the fisherman is fishing at the reef margin, it could easily take half an hour to complete the interview, thus increasing the incentive to go after less time-consuming catch/effort interviews.

Figure 4 .

INSHORE SURVEY FORM: PARTICIPATION

DIVISION OF AQUATIC & WILDLIFE RESOURCES
DEPARTMENT OF AGRICULTURE
GOVERNMENT OF GUAM

INSHORE CREEL CENSUS

Date _____

WE/H WD

Interviewer_____

Inter-
view
No.

No. of Persons	No. of Gear Units &
-------------------	---------------------------

Reef zone

Weather & Water Conditions

This image shows a full page of blank graph paper. The paper has a light gray background with a grid of thin, dark gray lines. The grid consists of small squares, approximately 1 cm by 1 cm. There are no margins, text, or other markings on the page.

DEPARTMENT OF AGRICULTURE
GOVERNMENT OF GUAM

INSHORE SURVEY FORM:
CATCH/EFFORT

Interview # .

Interviewer

INSHORE CREEL CENSUS

Location	Date	WD	WE	Interview time
----------	------	----	----	----------------

Method:

1. Hook & Line _____ Bait _____
3. Gill Net _____ No. Sets _____
4. Surround Net _____ No. Sets _____
Speargun _____ 5. Snorkel _____
7. Octopus Hooks _____

2. Cast Net _____ No. Casts _____
 Length _____ Mesh _____
 Length _____ 8. Dip Net _____
 6. Scuba _____ 9. Other _____
 Reef Zone _____

TYRE DATA : 1 3 1 2 3

[illegible]

TYPE DATA	1 ACT	2 CALC	3 EST
TOTAL NO. FISH			
TOTAL WT. (kg)			
TOTAL NO. SPP.			

No. Fishermen	Weather
Start Time	Cloud Cover
Lost Time	Lunar day
Stop Time	Surf
Time Most Fish Caught	
Wind Dir.	Swell Dir.
Wind Speed	Tide

Participation data is collected at offshore boat launch areas also. The inshore survey attempts to obtain an estimate of fishing participation for both inshore and offshore activity. Results from the aerial survey show that fishery participation among the three regions is fairly similar: Region 1 - 37 percent; Region 2 - 30 percent; and Region 3 - 33 percent.

Expansion methods for inshore activity follow the techniques used in previous years. Mean values for catch, participation, and effort were calculated separately by WE/H and WD for each month and each fishing gear. Where current data is missing, the appropriate numerical estimate is derived from past information. These values are then multiplied by the total number of WE/H and WD within that month. Following the necessary summation process, the desired estimates are obtained. To date, the above estimates are not adjusted for variable weather conditions (although the offshore survey is beginning to account for weather), people fishing in non-surveyed areas, night fishing, fishing performed at times of the day other than during sampling periods, nor the occurrence of illegal methods.

ASSESSMENT OF CURRENT SYSTEM

This final element of Section I is included for the purpose of assessing the sampling methods just discussed.

General Comments

The following comments address those areas where additional considerations and actions may be required. These comments are not necessarily presented in order of importance to the system.

Documentation Needs. A fundamental requirement of any data collection effort is the development and continual maintenance of written documentation explaining completely each aspect of the data collection system, its methods and procedures. Presently, the sampling programs are well-documented only in the minds of each sampler. The DAWR needs to develop in-house written documentation detailing all aspects of the data system. As a minimum, this document should include the sampling design, sampling levels and effort, sampling methods and procedures, a sampler's log book, guidelines for sampler training, a discussion of ideas that have worked or not and the reasons. This source document would be of real value to future data collection efforts.

Compatible Data Set. Undoubtedly, in the future, the DAWR will be asked to provide fishing data to a variety of individuals and agencies. Soon the data files will be accessible by computer; this will greatly increase the flexibility and scope of the division's data analysis capabilities. To assist in this endeavor, the DAWR should consider developing a data set which is compatible throughout each of the surveyed years. This effort may require devising a series of bridges between

different years. At the very least, the DAWR should review the feasibility of implementing this suggestion. In addition, current and future data collection activities must be looked at in terms of this compatibility issue. Therefore, when procedural or sampling changes occur, a corresponding adjustment should be made to the data set if necessary to insure compatibility.

Judgmental Sampling Procedures. As in any sampling scheme which requires the sampler to make sampling decisions, the collection of fisheries data introduces a judgmental element to the sampling designs. Whenever judgmental sampling enters into a sampling program, the possibility of introducing additional bias into the system exists. Both sampling programs at hand require a number of decisions by the sampler as to when, where, and to whom a questionnaire should be administered.

To assist the sampler in making these types of decisions, and to avoid possible bias problems, the programs should develop a series of general sampling guidelines. For example, during an off-shore creel survey, the possibility exists for the arrival of more than one boat at a time and the sampler is faced with the dilemma of which boat to sample. Instead of arbitrarily deciding which boats to sample, the sampler could draw from a set of guidelines as to which type of boats, gear, and fishing locations should be sampled first. A mini-questionnaire could be developed to assist the sampler in determining the proper boats to be fully interviewed. A similar set of guidelines would be valuable to the inshore sampling program.

PREFACE

This report was prepared under contract (No. 82-ABC-00224) by CIC Research, Inc. of San Diego, California. The objective of the contract was to develop and recommend a statistically sound fisheries data collection system for the Government of Guam, Division of Aquatic and Wildlife Resources. To do this the contractor made an on-site visit to study the historical data and data collection methodologies used by the Division. Survey techniques and expansion algorithms were developed. Since this report was prepared under contract, the statements, findings, conclusions, and recommendations herein are those of the contractor and do not necessarily reflect the view of the National Marine Fisheries Service.

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September 30, 1983

Continual Review of Sampling Procedures. Whenever a sampling procedure is to be added, changed, or deleted, it is important to understand the reasoning behind the adjustment. A number of the sampling procedures developed over the years and currently in use by the DAWR fail to satisfy the above condition. A couple of examples will illustrate this point. Currently, inshore and offshore sampling days do not occur on the same day. The reason for this policy has not been clearly delineated. Another example involves the allocation of sampling effort between WE/H and WD. When the sampling results are processed, calculations are made separately for WE/H and WD data. Correspondingly, the sampling effort is divided equally between the two periods. Again, the reasoning behind this equal sampling allocation was never fully stated.

Each element of the data collection system must be carefully reviewed and adjusted if it no longer meets the needs of the current program. Valuable effort can easily be wasted if the program relies unnecessarily on out-dated methods. Section II attempts to address some of these elements; nevertheless, it is strongly suggested that the DAWR carefully review the sampling program with the above considerations in mind.

Expansion Algorithm. Another essential element of the data collection system is the method employed to generate the numerical estimates concerning fishing activity. Because the expansion algorithm defines the connection between the sampling data

and the final estimates, it is essential that it fully accounts for all factors influencing the fishing activity on the Island. For example, suppose that sampling occurs only during the day and that the occurrence of night fishing is common knowledge. It is inappropriate for the expansion algorithm to ignore the night fishing activity. By so doing, the methodology implicitly assumes a zero value factor for night fishing. Although the factor used to estimate night fishing may lack the desired statistical properties, nevertheless, it is at least possible to devise a plan which provides a cursory estimate of activities. If the researcher believes that a zero factor is preferable to a "ball park" estimate, then at least the issue has been addressed. In any event, the expansion method must, in principal, fully account for the entire fishing activity. The weather adjustment now utilized for the offshore estimate is a step in this direction.

Cocos Lagoon Area. The sampling program now in place virtually ignores the fishing activity in Cocos Lagoon. This area apparently is one of the most active fishing areas on the Island and needs to be sampled on a regular basis. The use of a telephone survey was attempted in hopes of gathering the desired information, but it failed. Although telephone surveys in other locations in the U.S. have proved successful in collecting certain types of fishing data, the problem of language and telephone coverage prohibits a telephone survey from working in Guam.

Hopefully, the DAWR will soon seriously consider future data collection efforts in the Cocos Lagoon.

Offshore Sampling Program. While the inshore fishing activity presents the most immediate concern of the DAWR, it is critical that the Division not diminish the offshore sampling effort. From an economic point of view, the offshore fishery may have the greatest impact on the future of Guam.

Objectives of Offshore Program. The offshore sampling program identifies two sets of objectives. The first set deals with collecting the necessary information required to monitor offshore activity, while the second set considers the importance of obtaining the maximum number of interviews per unit of time. The DAWR should consider the compatibility of these two sets of objectives.

Scope and Structure of Offshore Program. Over the years, the offshore survey apparently has become somewhat myopic in nature. Currently, only the Agana Boat basin is being sampled, and only in the afternoons and evenings. This is not necessarily incorrect methodology; at issue is how well this approach reflects Island-wide offshore fishing activity. The participation survey (inshore program) now under way is a positive step in addressing the offshore fishery in its Island-wide perspective. Instead of starting with a single sampling element and expanding to the entire Island, the proper perspective entails first developing a sampling strategy for the entire offshore

fishery, and then determining which elements can be adequately sampled and which elements must be estimated by other means. Apparently, the vast majority of elements of the sampling program exist and are properly in place. What is missing is a formalized structure to the program, so that the program can be reviewed easily and adjusted if required. The quality of the data currently collected at the boat basin appears to be good.

Public Relations Needs. Good public relations are essential to a successful sampling program, and the samplers have developed the necessary rapport with the fishermen to obtain high quality information. In addition, Robert Meyers has recently published a book on Guam's fisheries which could be an excellent vehicle to further enhance the good relationship between the fishermen and DAWR. Presenting the fishermen with a book, or other appropriate item at the close of the interview could reap rewards in terms of better cooperation. With only a few such adjustments, the offshore program will be able to fulfill its intended objectives.

Inshore Sampling Program

The inshore sampling program is essentially a participation survey this year. For this reason, a few factors must be considered when assessing the program.

Mechanics of Inshore Program. The mechanics involved with the inshore survey require special skills. The sampler must be able to view fishing activity under numerous conditions and from a variety of locations. Often, finding these observation areas can be difficult for the untrained observer. The DAWR is fortunate to have experienced individuals with extensive training in biology conducting the sampling. This high level of expertise not only results in high quality data being collected, but greatly enhances the efficiency of the sampling. To assist the sampler in observing the fishing activity around the Island, powerful binoculars are needed. The sampler must be able to not only identify a fisherman, but also be able to determine the gear being used. The binoculars currently being used for these tasks are not adequate.

The sampling route is unique, hence it would be advisable to chart the route on a map to assist future sampling efforts, especially in case of personnel changes. Accompanying this map should be a narrative describing the route in light of existing road signs and markings.

Another area of concern with the inshore sampling procedure results from beginning the survey at one of only two possible points. By having only two possible starting points for the survey, the time at which samples are taken becomes predictable. For example, Gun Beach is sampled only in the mornings or late afternoons, never at any time in between. The DAWR should consider randomizing numerous starting points

and then begin the sampling in a continuous manner from there. Granted, this will add additional driving time; however, a more randomized sampling program will result. In addition, by staggering the sampling hours to include early morning and evening fishing, better overall coverage of fishing activity will result.

Catch/Effort Data Requirements. Although the inshore sampling program is essentially a participation survey, the sampler must obtain catch/effort data whenever possible. Unfortunately, the nature of the program creates a significant incentive for the sampler to take only "easy" samples. If in fact this is true, then these "easy" samples could introduce unnecessary bias into the sampling program. The DAWR looks upon the current program as a short term activity.

DAWR's Capability

The ability of the DAWR to sample inshore activity is only limited by its manpower resource. The basic elements of proper sampling techniques are understood by the DAWR and for the most part have been incorporated into the system.

Expansion Algorithm. One significant problem occurs in the expansion methods employed by the DAWR, however. A number of factors, i.e., weather, night fishing, etc., which readily impact fishing activity have not been accounted for in the expansion method. The DAWR must begin to develop estimates of these factors either through sampling or by some other means.

Best Participation Survey Method. Finally, in terms of the participation survey, the aerial survey appears to provide the best estimates of inshore activity.

Concluding Assessment

All things considered, the current sampling programs are working well. In recent years, the DAWR has made great strides in implementing a useful fishery data collection system. Existing deficiencies can be easily corrected within current budgeting constraints. The result will be a viable system which will enable the DAWR to accurately monitor the Island's fishing activity. The overriding factor which will allow this system to operate successfully is the caliber of people participating in the project. These individuals are willing to experiment in looking for better methods and techniques. Finally, the DAWR must play the central role in collection of fishing information now and in the future.



SECTION II

PROPOSED FISHERY DATA COLLECTION SYSTEM

INTRODUCTION

This section of the report formalizes the initial steps in developing a complete Fishery Data Collection System by establishing the fundamental elements of the system. At the foundation of the FDCS are two basic principles. First, the system must be built on sound conceptual and statistical principles. In this regard, the discussion of the sampling design and expansion techniques are critical. Second, any data collection system proposed must fit within the constraints imposed by Guam's existing fishing culture. Thus, the proposed FDCS's structure draws heavily from current as well as past data collection methods and techniques. In fact, the proposed system is essentially a composite of these tested methods. For ease of study, the proposed FDCS is divided into eight elements. These elements are:

- Description of the FDCS objectives
- general design components for the FDCS
- sampling design
- sampling activity procedures
- processing of the system's data base
- expansion algorithms and their reliability

- quality assurance methods
- presentation of the FDCS's results

The primary focus of this section is on the sampling design and expansion algorithm elements. Discussion of the remaining six elements is limited in content to those matters which directly pertain to the sampling design and expansion algorithm factors. In addition, at times, alternative strategies will be identified and discussed in an attempt to provide a complete presentation of the FDCS and its development. Each of the eight components to the FDCS is presented and discussed individually in the remainder of the section.

OBJECTIVES OF A FISHERY DATA COLLECTION SYSTEM

The objectives of a FDCS provide the conceptual background needed in directing the collection of fishery information. The FDCS's objectives reveal what universe is to be studied, in a statistical sense. Within the universe, the objectives identify which characteristics are to be observed and measured and which structural processes are to be examined. Each year, the DAWR states in its annual fishery report the objectives of the data collection efforts for that year. These stated objectives describe the goals surrounding the data collection effort.

The DAWR was asked to review its past objectives and goals with regard to data collection activities, and to identify a set of objectives which would serve as a basis for the proposed

FDCS contained in this report. As a result of this effort, the overriding objective for a FDCS on Guam is to obtain reliable Island-wide total harvest estimates. The nature of the fishing activity is such that the fishing on Guam can be naturally divided into inshore and offshore activity. Thus, the primary objective translates into generating Island-wide catch estimates for both inshore and offshore activity.

To assist in developing meaningful Island-wide estimates, DAWR identified key characteristics which must be examined closely. These characteristics include fishing effort, participation, fishing gear used, area fished, and species catch compositions for both the inshore and offshore fisheries. To insure that these characteristics are properly analyzed, adequate sampling effort must be undertaken. The objectives for the proposed FDCS can be summarized as follows:

To obtain reliable Island-wide total harvest estimates as well as obtaining estimates of catch and effort with respect to fishing method, fishing areas, and species composition.

GENERAL DESIGN COMPONENTS FOR A FISHERY DATA COLLECTION SYSTEM

General design components refer to these considerations which must be examined in the formulation of the overall sampling design approach. In effect, these components act as framing constraints to the system and encompass three areas: the fishing experience, sampling factors, and sampling effort. These three areas are undoubtedly influenced by each other's activities.

The Fishing Experience

Understanding the fishing experience enhances the likelihood of selecting the proper structure for the data collection system. There are three aspects to the fishing experience: the human, spatial and temporal. First, consider the human aspect of the fishing experience. Since it is the individual who participates in the fishing experience, the fishing experience must be measured in terms of the fisherman's activities.* Information concerning the fisherman's catch and effort must be compiled as well as the overall fishing participation.

The human element is comprised of two groups: fishermen and non-fishermen. The fishermen and non-fishermen make up the population needed to determine the participation rates often used when assessing fishing activity. Therefore, in order to derive the necessary participation rates, information concerning the relative sizes of these two groups must be known. Unfortunately, this information is not available on Guam. The closest information which could be used to extract participation rates comes from the National Recreation Fishing Survey conducted by NMFS. However, in talking with the DAWR and reviewing the 1979 results, the consensus was reached that the participation information available from this recreational survey did not reflect the true levels of participation, and significantly underestimated the activity. Hence, the use of participation figures in evaluating fishing activity must be de-emphasized.

* On Guam, fishermen fish for one of three reasons: recreation, subsistence, and commercial.

Because Guam is an island, the second factor in the fishing experience, the spatial factor, is well-defined. In principle, fishing could take place anywhere on the Island's coastline. Thus, the FDCS must define some means of determining what level of fishing effort is occurring at a specific location. In the case of the offshore fishery, this will involve assessing the launching sites around the Island and determining how best to examine these sites. The variety of possible methods for examination is broad, ranging from actual sampling to ignoring the site completely. Critical to the data collection system is assigning a method to each site so that the entire Island is covered. Any spot which is omitted could introduce unnecessary bias into the system. As a rule, examination methods should be re-evaluated periodically.

A similar approach must be taken for the inshore fishery. The entire shoreline of the Island must be reviewed and a method for measuring the fishing activity determined. It is important to note that due to any number of reasons, e.g., budgetary, safety, it is possible to omit an area from consideration. However, without the use of a proxy measure, one must realize that omitting an area explicitly assumes zero fishing activity for that area.

The final factor in the fishing experience is the temporal factor. The unit of measure is a day. Of essence here is the coverage aspect of the factor: the FDCS must take into account

the entire unit of measure, a 24-hour day. The simplest division for this factor is day fishing, i.e., dawn to dusk and night fishing, i.e., dusk to dawn. Some means of estimating the fishing activity during these hours must be developed. For Guam, the major temporal problem is the night fishing activity which will be discussed further in the next element of the FDCS -- the sampling design. Both the inshore and offshore fisheries must be viewed from this temporal dimension in order to insure a complete FDCS. By combining the three fishing experience factors, a better insight is gained into the feasible approaches to the FDCS.

Sampling Factors

Sampling factors represent the second design component. A number of sampling factors exist which, upon identification, assist in revealing the most promising sampling procedures to be followed. First, the determination unit must be specified, i.e., what items are to be sampled and measured. For both the inshore and offshore fisheries, this unit is ultimately the fisherman.

The nature of the fishery and the program's objectives are such that the measurements at another level, i.e., the retail outlet, would not lead to satisfactory results because not all fishermen sell their catch to retail outlets. Also, sampling at the fishermen level reduces the chances of losing information about basic fishing data. At times, the offshore sampling

activity at Agana Boat Basin may have to rely on the Guam Fishermen's Coop for the trip information, should a fisherman be missed. In most cases when this occurs, the Coop is able to identify the fisherman and the missing information is obtained. Nevertheless, the objective of any sampling scheme should be to interview the individual doing the fishing.

While the name associated with the present sampling schemes uses the word "census," these programs do not collect information on all participants. The proposed FDCS will rely heavily upon sampling methods. Two sampling methods will be employed: face-to-face interviews and sampler observation. Other means of sampling, such as telephone sampling or mail sampling, would not provide the quality of data desired. The face-to-face interviews will be directed at the fishermen in the hopes of obtaining information not otherwise available, specifically catch and effort information. However, in the collection of participation data, sampler observation methods should be utilized whenever possible.

Sampling Effort

The final design component to be considered deals with sampling effort. Three factors influence sampling effort: costs, variability, and tolerated error. In the real world, budgetary considerations are the fundamental constraint to sampling effort. For Guam, the availability of funds is to a large extent independent of need. Instead, Guam is faced with the age old problem of cutting up the pie among many claimants. Exact costing figures for existing sampling programs are not readily available.

However, estimates of the variable cost of the sampling programs, made available by the DAWR, showed that for the inshore surveys the cost per interview was approximately \$2 to \$3, while offshore figures ranged from \$3.50 to \$4 per interview. These figures translate into a daily cost of \$52 for the inshore survey and \$44 for the offshore survey. While no fixed cost information is available, this variable cost information will assist in evaluating the financial feasibility of alternative FDACS's especially in terms of specifying sampling effort.

Another element of the sampling effort issue is the variance associated with key variables. The greater this variability, the greater will be the required sampling effort to obtain a reliable estimate. The existing fishery data set, which the DAWR is now computerizing, will furnish valuable variance estimates. Finally, DAWR selected a target confidence level and tolerated error for the program; the values were 95 percent and 10 percent, respectively. Tables 5 and 6 contain the sample sizes for generating fishing estimates for the primary fishing methods for both offshore and inshore sampling.

To illustrate sampling effort sensitivity to selected tolerated error values, sample sizes were computed for three separate error values. The proportions used in computing the variances were five-year averages derived from the DAWR data set. The inshore proportions were derived by averaging inshore creel and aerial participation rates.

Table 5

COMPUTED SAMPLE SIZES FOR VARIOUS
TOLERATED ERRORS BY SELECTED
FISHING METHODS: OFFSHORE SURVEY

<u>Fishing Methods*</u>	<u>Tolerated Error</u>		
	<u>.05</u>	<u>.10</u>	<u>.25</u>
Trolling	340	90	15
Bottom Fishing	3,790	1,800	385
Spearfishing	4,800	3,010	830

* Participation rates used were .81, .13, .06, respectively.

Source: CIC Research, Inc., 1983.

Table 6

COMPUTED SAMPLE SIZES FOR VARIOUS
TOLERATED ERRORS BY SELECTED
FISHING METHODS: INSHORE SURVEY

<u>Fishing Methods</u>	<u>.05</u>	<u>.10</u>	<u>.25</u>
Hook and Line	2,640	595	100
Cast Netting	4,120	1,490	275
Gill Netting	3,275	1,085	190
Surround Netting	4,465	1,680	315
Spearfishing	5,070	2,045	395

* Participation rates used were .30, .18, .24, .16, .13, respectively.

Source: CIC Research, Inc., 1983.

In computing the sampling values in Tables 5 and 6, the following formula was used:

$$(1) \quad n = \frac{N \cdot Z^2 \cdot (P(1-P))}{N \cdot e^2 + Z^2 (P(1-P))}$$

where

n = sample size estimate

N = population size estimate

Z = standard normal variate

P = proportion of fishermen using a given fishing gear

e = tolerated error

Equation (1) was selected because the sampling effort is directed towards the binomial decision of fishing or not or using a given gear compared with all other gears. Essentially, the sampling program measures the fishing activity on the Island. Therefore, if the program is to generate measures of fishing activity, adequate numbers of fishermen must be interviewed. Since the gear used by the fishermen is descriptive of the fishing activity, sampling effort is presented in a gear-specific manner. Hence, a binomial approximation underlines Equation (1). Thus, implicitly, the assumption is being made that fishing gears are independent. While exceptions to the assumption can be observed, their magnitude is insignificant as long as the fishing gear activity can be reported in an independent manner. For example, a fishing vessel on a single trip may troll and bottom fish.

If the fisherman is able to separate the effort and catch related to these methods, the sampler can report these as two separate trips.

Current sampling levels are such that their relative size to the population as a whole requires the inclusion of the finite population correction factor in Equation (1). With annual sampling levels ranging from 2,000 to 3,000 interviews for the inshore survey and 800 to 900 interviews for the offshore survey, a lower bound estimate of the population can be derived. For the purposes of Equation (1), the population estimate for inshore activity is 10,000 trips and for offshore activity, 6,000 trips. Thus, under current sampling levels, approximately 20 percent of the inshore trips are being sampled and 15 percent of the offshore.

In computing the sample sizes for Tables 5 and 6, it is important to note how the tolerated error (e) value is calculated. Tolerated error can be viewed in either an absolute or relative sense. In its absolute sense, the value of the error term is a number independent, for the case at hand, of the fishing gear participation rate.* In other words, an error value of 10 percent will generate estimates within 10 units of the participation rate. Therefore, if the participation rate equals 20 percent, the acceptable range becomes 10 to 30 percent. Tolerated

* See "A Recommended Approach to the Collection of Marine Recreational Finfishing and Shellfishing Data on the Pacific Coast." Contract No. 6-35339, National Marine Fisheries Service, Data Management and Statistics Division; Washington, DC, August 1977, pp. 15-18.

error in its relative sense implies the error value is dependent upon the participation rate under consideration. Hence, an error value of 10 percent will generate estimates within .1 times P (participation rate). Following the above example, with a 20 percent rate, the acceptable range in this case becomes 18 to 22. For the purposes of equation 1, the tolerated error term is calculated in its relative sense.

Tables 5 and 6 show the total number of trips that must be sampled in order to adequately cover a specific fishing method. For example, in the case of the offshore fishery, 3,010 fishermen must be interviewed to obtain an acceptable spearfishing estimate within the parameters defined, i.e., tolerated error. A review of the offshore fishery sampling requirements (Table 5) shows that at the 10 percent tolerated error value, current sampling levels adequately survey only trolling. In the case of bottom fishing and spearfishing, current sampling levels result in a tolerated error in the neighborhood of 20 and 25 percent, respectively. For the inshore fishery (Table 6), current sampling effort meets the desired levels, i.e., 10 percent tolerated error. In conclusion, the current levels of sampling yield numerical results which can be considered worthwhile.

THE SAMPLING DESIGN

The sampling design describes the procedures to be followed in generating the desired data base. The overall design is

comprised of two basic methods: statistical survey methods and qualitative inference methods. A statistical survey method refers to those procedures which involve observing fishing activity in a systematic fashion and relying on sound statistical survey theory. Qualitative inference methods, on the other hand, do not rely upon a statistical basis but involve more arbitrary observation techniques and procedures.

Three survey procedures comprise the set of statistical survey methods proposed, while two qualitative methods are required to insure completeness of the FDCS's sampling design. The three survey procedures are: an offshore sample survey, an inshore sample survey, and a Merizo area survey. The two qualitative methods are aimed at quantifying night and illegal fishing activity. Together, these methods -- the statistical survey and qualitative inference methods -- will generate a data collection system which will provide a complete estimate of Guam's fishing activity. Each of these methods will be discussed in detail below.

Statistical Survey Methods

Each of the three survey methods is directed towards obtaining information concerning daytime fishing activity. The purpose of the three survey methods is to identify and provide an estimate of a particular portion of the daytime fishing activity. In addition, the three methods were designed in

such a manner as to insure that the proper expansion could be made.

Geographical Division of Coastline. The DAWR has developed a fairly specific geographical coding system to assist in identifying the location of the fishing activity. In the system's most general sense, the Island is divided into surveyed and non-surveyed coastline. Within the surveyed coastline are the three survey regions -- Regions 1, 2, and 3. Next, each region is divided into areas. In Region 1 are the Tumon and Agana areas, in Region 2 are the Asan/Piti, Harbor and Agat areas, and finally, in Region 3 are the Manell/Inarajan and Talofofo/Pago areas. The most notable area missing from the current surveyed coastline is the Merizo area.

The final level of disaggregation is referred to as sectors. In all, the entire coastline of Guam is divided into 92 separate sectors. Sector 1 is located at Gun Beach with Sector 92 located just north of Gun Beach. The following table shows the relationship between the different geographical sectors. This geographical division of the coastline will assist the sampler in uniquely identifying the fishing location of each sighted fisherman or vessel trailer.

Table 7

GEOGRAPHICAL DIVISION OF
SURVEYABLE COASTLINE

<u>Region</u>	<u>Area</u>	<u>Sector</u>
1	Tumon	1 - 4
	Agana	5 - 11
2	Asan/Piti	12 - 15
	Harbor	19 - 27
	Agat	28 - 36
	Merizo	42 - 50
3	Manell/Inarajan	51 - 57
	Talofofo/Pago	60 - 72

Variability of Fishing Activity Between WE/H and WD. Data collected during 1980 and 1981 shows that 44 percent of all fishing activity occurred on WD, while 56 percent of the activity occurred on WE/H. If, in fact, significantly different rates of fishing exist between WE/H and WD, it must be reflected in the proposed survey design. Unfortunately, a review of the DAWR's participation data between WE/H and WD showed a considerable amount of variability.

In order to properly account for the difference in variability, sampling effort must be stratified by WE/H and WD. Should the DAWR desire separate estimates for WE/H and WD, additional sampling effort will be required. The DAWR should closely analyze this WE/H and WD information to determine the most beneficial course of action.

Impact of Weather on Fishing Activity. Changes in weather influence fishing participation for both inshore and offshore activity. These factors must be incorporated into the survey design and results (see Malvestuto, et al., Trans Am Fish Soc. 1979). Along with the fishing information collected, DAWR maintains a record of weather conditions. DAWR should study these data and correlate the relationship between climatic variables with fishing activity. If necessary, a separate study should be undertaken to develop these relationships. Once the desired relationships have been compiled and statistically supported, they can be used. As needed, periodic updates of coefficients can be undertaken.

The current offshore survey methodology attempts to account for varying weather conditions by adjusting the number of available fishing days -- a measure of normal fishing days. From the total number of available fishing days, the number of bad weather days (i.e., no fishing days) and the number of poor fishing days (i.e., less than normal days based on the issuance of small craft advisories) are subtracted out. For example, a poor fishing day may correspond to three-fourths of a normal day.

General Design of Surveys. The foundation of the proposed sampling designs is based on a paper by Malvestuto, et al, entitled "An Evaluation of the Roving Creel Survey with Nonuniform

Probability Sampling."* In this paper, the authors detail an application of the roving creel survey with non-uniform probability sampling. The basic procedures outlined in this paper can be adapted to sampling activity in Guam. Essentially, the sampling scheme generates an unbiased sampling and estimation of fishing success. Fishing success is defined as the weight of fish caught per fisherman hour or catch per unit effort (CPE).

The basic features of this proposed approach can be summarized as follows:

1. The entire period for which the fishery is to be surveyed is divided into time blocks. Ideally, the amount of fishing expected to take place within these blocks should be similar. DAWR should review past fishing data and determine the most appropriate division of these time blocks. This review must take into account various seasonal factors, i.e., species, climate, etc. Currently, these time blocks are one month in duration. For the purposes of this study, the one-month figure will be used.
2. Each time block is divided into sampling units. A sampling unit defines the time periods during which sampling will take place. In addition, all of the fishing time within a block is contained within the sampling units and the units do not overlap.
3. Assigned to each sampling unit is a sampling probability proportional to the amount of fishing expected for that unit. The sum of probabilities assigned to the sampling units within any given block equals 1.0.
4. Sampling units are randomly chosen within each block on the basis of the assigned sampling probabilities. Therefore, there exists a proportional relationship

*See "An Evaluation of the Roving Creel Survey with Non-uniform Probability Sampling." by Stephen P. Malvestuto, William D. Davies, William L. Shelton; Transcript American Fishery Society 107(2): 255-262, 1978.

between the probability that sampling will actually be done during any given sampling unit, and the amount of fishing occurring during the unit.

5. Sampling activity is comprised of two components: fishermen counts and catch/effort interviews. Multiple gear trips must be counted as a separate trip for each gear used. This is true for both the offshore and inshore fisheries. The sampler will have to allocate certain responses to each gear, e.g., fishing effort.

Offshore Sample Survey. The offshore survey is a sample survey and its purpose is to obtain estimates of catch and effort activity within the offshore fishery. As Table 2 showed, of the three principal offshore fishing methods, trolling is by far the most prevalent fishing method. Essentially, the offshore survey now in operation in Guam is the basis for the proposed offshore survey. Therefore, this discussion will focus on formalizing the offshore survey operation with the proposed general design.

The offshore sample survey has a simple random sample design. There are a number of reasons for this. While a number of boat mooring and launching sites exist around the Island, basically all catch/effort sampling is done from two basins, Agana and Merizo. DAWR estimates that the activity of these two basins accounts for well over 90 percent of the offshore fishing activity. The infrequency of offshore activity elsewhere precludes any meaningful sampling of catch and effort information. Hence, the offshore survey cannot effectively sample areas outside of these basins. However,

activity outside these basins will be partially observed by the inshore survey and incorporated into the overall survey results; participation estimates in these infrequently used offshore launching areas are being compiled by DAWR and can be used as a check when reviewing the offshore activity.

Two underlying assumptions are made to insure that the data generated are complete. First, the assumption is made that no offshore activity originates from outside DAWR's three regions. Second, it is assumed that the catch/effort figures collected from these two basins do not differ from the other offshore launch areas.

Special circumstances surrounding the Merizo area, i.e., the need to combine the inshore and offshore sampling activity, require a separate survey. (See discussion on page 69.) Hence, the offshore sample survey consists of sampling one basin, the Agana Boat Basin. However, as offshore activity increases around the Island, and the need for additional sampling is required, the sampling program can easily be expanded. For example, it may become necessary to group the boat basins, one group being sampled within any one sampling unit. The groups are randomly chosen with probability proportional to the amount of fishing expected to occur in that group.

The subsampling unit is the fishing vessel with the observation being made of the fisherman and his catch. On an offshore sample day, the sampler observes and intercepts boats as they

return with the objective of collecting catch/effort information. In addition, the sampler maintains a count of departing and returning fishing vessels.

An important issue for a sample survey involves coverage, that is, obtaining data on each observation unit. The sampler need not spend the entire day at the basin if the catch/effort data does not vary by time of return. While the majority of boats return in the later afternoon and early evening, the sampler must be sure that the catch/effort results obtained during these periods do not differ from earlier times of the day. This issue can easily be tested by simple statistical mean difference tests using existing data.

During the course of the sampling, the sampler must be aware of the activities in the boat basin. Should a number of boats arrive in the basin at the same time, the sampler may have to undertake subsampling procedures. If this occurs, the proper notation should be made. The objective of the sampler is to survey all the boats on a survey day. When this cannot be done, the decision as to which boats to sample should be determined by the type of fishing gear and/or location of fishing in an appropriate sample allocation scheme. Fortunately, the sampler, in the case of the offshore fishery, is dealing with completed fishing trips.

In keeping with the present continuous sampling program, a one-month time block is proposed for the offshore survey.

The blocks are divided into two sampling units: A.M. and P.M. DAWR estimates that the average offshore fishing trip is one day, or 12 hours (fishing time). Primarily, boats leave in the early morning hours and return in the late afternoon or early evening. Thus, according to DAWR, the vast majority return during the P.M. unit. DAWR must assign to each sampling unit a sampling probability proportional to the expected return of the fishing vessel. These probability values are derived by reviewing historical data on when boats returned and computing the proportion of boats returning in the A.M. and P.M.

Activity at the boat basin appears to differ between WE/H and WD, with WE/H being more active. An analysis of 1982 offshore catch data shows that the average WD catch for trolling was 38 kg, while the WE/H averaged 30 kg. Interestingly, no statistical difference between these two mean values existed at the $\alpha = .1$ level.

For the purpose of this sampling scheme, the periods WD and WE/H are treated separately, i.e., the sampling scheme is stratified. The primary reason behind this treatment is the different participation level between the two periods. Should the DAWR decide after reviewing the entire offshore data set (i.e., for more than one year) that such a distinction is not required, the sampling effort can be reduced.

Current sampling levels, i.e., four sample days, will allow eight different sampling units to be observed. Each sampling

unit is to be randomly selected within each one-month block on the basis of the assigned probabilities. First, however, sampling units are equally stratified by WE/H and WD (four sampling units each. Giving all days within a strata equal probability of being selected, four sample days are chosen. Then, within a sample day, the sampling unit (A.M. or P.M.) is selected according to the proportional probability computed above. One would expect that the vast majority of sampling would be done in the P.M. period.

Inshore Sample Survey. The inshore survey is also a sample survey and its purpose is to collect information concerning catch and effort activity by the inshore fishermen. Of the five major fishing methods utilized by the inshore fishermen, hook and line is the most prevalent inshore fishing method, while surround netting accounts for the greatest proportion of catch (35%). The inshore sampling program which the DAWR has used in the past to collect catch and effort data will serve as the foundation for the proposed inshore survey.

The proposed inshore survey follows the general design previously presented, but also introduces a stratified area sampling design. Because the size of the Island's surveyable regions is so large, it is necessary to divide the Island into more manageable groups. Like the offshore survey, the inshore survey is a continuous program. Again, one-month time blocks are proposed.

The survey is directed towards obtaining daytime catch information. Each time block is divided into three sampling units: A.M., Noon, P.M. Basically, these units encompass the following time intervals:

A.M. - Dawn until 1000 hrs.

Noon - 1000 hrs. until 1400 hrs.

P.M. - 1400 hrs. until dusk

The above sampling units define the temporal component of the sampling scheme.

The area sampling element must be addressed. Area sampling is a term commonly used when the sampling activity is based on geographical areas. The survey is designed to intercept the fishermen along the coastline. Using the geographical divisions developed by the DAWR, the following stratification system has been developed.

As mentioned earlier, DAWR defines the Island's coastline into surveyed and non-surveyed regions. Non-surveyed regions represent those areas where either fishing accessibility is restricted or observation of fishing activity is not possible. During the aerial survey, it was possible to obtain participation estimates for the entire Island, surveyed as well as non-surveyed regions.

Table 8 indicates the proportion of fishing activity between the two types of regions by fishing gear (figures taken from Table 1). The rates shown in Table 8 are used in computing

Table 8

PARTICIPATION RATES FOR FISHERMEN IN SURVEYED
AND NON-SURVEYED REGIONS BY FISHING METHOD

<u>Fishing Method</u>	<u>Participation Rate</u>	
	<u>In Non-Surveyed Regions</u>	<u>In Surveyed Regions</u>
Hook and Line	.069	.931
Cast Net	.204	.797
Gill and Surround Net	.099	.901
Spearfishing	.200	.800
Other	.211	.789

Sources: DAWR
CIC Research, Inc.

proportion of fishing in non-surveyed regions. The computations for the non-surveyed regions are presented in the expansion algorithm section. The first level of stratification is the three survey regions. Over the past two years, 55.8 percent of the sampled catch occurred in Region 1 with 20.6 percent, and 23.6 percent in Region 2 and 3, respectively. For the inshore survey, sampling effort is allocated by the proportional size of first the particular area strata and then by the time period (sampling unit). Therefore, 56 percent of the overall sampling effort is to be allocated to Region 1 with Region 2 and 3 receiving 21 and 23 percent, respectively. Then, for example, the 56 percent allocated to Region 1 will be disaggregated proportionally to the three sampling unit time periods. DAWR can develop these probability values from their existing inshore data base. For a given region, interview responses are categorized into one of the three sampling units according to the time of the interview. From these groupings probability values are derived.

Since the late 1970's, DAWR has sampled the inshore fishery at a level of four to six days per month. On the surface, this level of effort meets the sampling requirement depicted in Table 6. To more precisely determine the sampling effort required for the inshore survey, an analysis of CPE figures should be undertaken. By computing the average CPE, by species if desired, and the appropriate variance, sample effort levels

Assigned to each element is a probability value comprised of the product of the sample probabilities for each region and time period. Once these values are derived, the sample for a given time block can be drawn.

On a given sampling day, one sampling unit (defined as above) is surveyed by a sampler. Primarily, the sampler's activities entail making fishermen counts and catch/effort interviews. The DAWR's inshore catch/effort and participation questionnaires address all the data information needs of this survey.

Once the sampler arrives at the desired region, he/she should make a count of fishing activity throughout the entire region. During this participation assessment effort, factors concerning location, gear, time, and weather conditions should be recorded. After the sampler has completed this portion of his/her activities, then catch/effort interviews are to be taken. Since the sampler has an idea of the current status of the fishing activity within the region; the sampler should be able to more efficiently interview the fishermen. By reviewing the participation results, the sampler will be able to allocate his/her time and interview a representative sample of fishing activity by gear.

For the most part, sampler's interviews will be made on incompleted trips. Thus, the assumption must be made that the CPE for incomplete trips equals the CPE for complete trips.

It would be worthwhile for the DAWR to conduct a study to verify this assumption. Also, a key variable to the expansion algorithm is the average length of the fishing trip. While this information is collected during the interviewing process, DAWR should consider conducting a survey dealing specifically with the average trip length issue.

Major Steps Required When Implementing Sampling Design:

- 1) Determine duration of time blocks: 1 month.
The survey period of one year has been divided into 12 time blocks.
- 2) Divide time blocks into sampling units:

Offshore Survey

Sampling units: A.M., P.M.

Inshore Survey

Sampling units: A.M., Noon, P.M.

- 3) Compute and assign sampling probabilities (P) to each sampling unit.

Offshore Survey

A total of four basic probabilities need to be calculated:

$P_{AM}^{WE/H}$ = For WE/H, the probability of an incoming vessel returning in A.M. hours.

$P_{PM}^{WE/H}$ = For WE/H, the probability of an incoming vessel returning in P.M. hours.

P_{AM}^{WD} = For WD, the probability of an incoming vessel returning in A.M. hours.

P_{PM}^{WD} = For WD, the probability of an incoming vessel returning in P.M. hours.

Computationally, the WE/H and WD probabilities are calculated separately. For example, WE/H specific data is reviewed to determine the number and subsequently the proportion of vessels returning in the A.M. and P.M. hours. Thus,

$$P_{AM}^{WE/H} = \frac{\text{the number of vessels returning in A.M. on WE/H}}{\text{total number of vessels returning on a WE/H}}$$

The other possibilities are computed in a similar manner when the appropriate substitutions are made. If the data is available, these probability values can be computed on a month-by-month basis. The quantity and quality of the data will determine the disaggregation level of these probability values.

Inshore Survey

A total of 18 basic probabilities need to be calculated:

$P_{AM, \text{Region } 1}^{WE/H}$ = For WE/H, the probability of a fisherman fishing during the A.M. hours in Region 1.

$P_{\text{Noon}, \text{Region } 1}^{WE/H}$ = For WE/H, the probability of a fisherman fishing during the noon hours in Region 1.

$P_{PM, \text{Region } 1}^{WE/H}$ = For WE/H, the probability of a fisherman fishing during the P.M. hours in Region 1.

Similar probabilities are calculated for Regions 2 and 3, i.e.,

$P_{\text{Noon}, \text{Region } 2}^{WE/H}$ $P_{PM, \text{Region } 2}^{WE/H}$ $P_{AM, \text{Region } 2}^{WE/H}$

$P_{\text{Noon}, \text{Region } 3}^{WE/H}$ $P_{PM, \text{Region } 3}^{WE/H}$ $P_{AM, \text{Region } 3}^{WE/H}$

In addition, another nine probabilities are computed for the WD period, e.g., $P_{AM, \text{Region 1}}^{WD}$, ...

To compute these possibilities, the survey data is categorized according to each of the nine probability descriptions for either the WE/H or WD group. For example:

$$P_{AM, \text{Region 1}}^{WE/H} = \frac{\text{the number of fishermen fishing in Region 1 in the A.M. hours on a WE/H}}{\text{the total number of fishermen fishing on a WE/H}}$$

If DAWR is unable to divide the survey data in the manner above, the similar probabilities of $P_{AM}^{WE/H}$ and $P_{\text{Region 1}}^{WE/H}$ can be computed with the product of these values equaling the desired joint probability.

4) Randomly Select Sampling Units

Offshore Survey

A total of eight sampling units are to be sampled each month. As an illustration, suppose the selection of sampling days is to be in February. For this example, February has 18 WD and 10 WE/H. The sampling is divided evenly between the two periods, four units for WE/H and four units for WD. A total of 36 sampling units are possible for WD and 20 for WE/H. In the case of WE/H, 10 sampling units are A.M. and 10 are P.M. Suppose 75 percent of the vessels return in the P.M. hours ($P_{PM}^{WE/H}$), the remainder returning in A.M. hours, 25 percent. Thus, of the four sampling units

to be surveyed, 3 ($4 \times .75$) will be surveyed in P.M. hours and 1 ($4 \times .25$) will be surveyed in A.M. hours. The particular days to be surveyed are then randomly selected, a total of four sampling days being selected.

Inshore Survey

The selection of sampling units for the inshore survey follows the same format, only the procedure is a bit more complicated. A total of 12 sampling units are to be sampled each month, six for WE/H and six for WD. Using the February sample again, a total of 54 sampling units are possible for WD and 30 sampling units for WE/H. In the case of WE/H for a given region, 10 sampling units are A.M., 10 units are Noon and 10 units are P.M. The six WE/H sampling units to be surveyed are determined according to the probabilities computed above. For example, if $P_{AM, Region 1}^{WE/H} = 15$ percent, then 1 ($.15 \times 6$) of the sampling units to be surveyed falls in the A.M., Region 1 group. The particular days to be surveyed are then randomly selected, a total of six sampling days are selected for WE/H period.

5) Conduct Survey

Merizo Area Survey. The two previous survey designs have omitted the Merizo or Cocos Lagoon areas (sectors 42-50) from consideration. The reason for this omission centers around the unique environment setting of the lagoon. Under the sampling scheme proposed for the remainder of the Island, it would be impossible to adequately survey the lagoon. While the offshore activity originating from the lagoon does not pose any special survey problems other than sampling logistics, the inshore activity is another matter. Inshore fishing can take place along the reef which protects the lagoon or in small vessels within the lagoon itself. The inshore activity cannot be surveyed without the use of a boat, which necessitates implementing a special survey for the area. In order to efficiently utilize sampling resources, the survey would combine the data collection efforts of both inshore and offshore activity. In addition, the DAWR should consider other biological studies that could be undertaken during the down time of the sampling activities.

Essentially, the sampling design for the Merizo area would follow the basic framework outline for inshore and offshore activities, except all surveys would be conducted during the same day. The Merizo survey could provide participation information, and the inshore and offshore catch and effort data. The prevalence of the major fishing methods used in the area are similar to Island-wide rates with the exception of inshore

spearfishing and hook and line methods. In the Merizo area, spearfishing accounts for 32 percent of the fishing participation while hook and line only constitutes 18 percent of the activity.

Overall sampling effort for this survey would appear to be between two and six days per month. This range is based on the sampling efforts required for the other surveys, along with a brief review of Merizo-specific fishing data provided by DAWR as well as meeting minimum coverage factors for each time period. To obtain a better estimate of the required effort, the DAWR should analyze the available Merizo data in terms of catch and effort statistics. This analysis would assist in determining the additional level of sampling effort necessary to generate the desired catch and effort information.

Qualitative Inference Methods

The previous sampling designs together provide a method for generating statistically based fishing estimates for daytime fishing on Guam. In order to complete the fishing picture on Guam, two additional fishing activities must be considered: nighttime and illegal fishing. Unfortunately, neither of these activities can be adequately sampled using a survey method. Instead, some other means must be employed to furnish an estimate of these two types of fishing activity which are basically limited to the inshore fishery. Each activity will be discussed separately.

Nighttime Fishing. According to the DAWR, nighttime fishing activity is prevalent enough to warrant numerical estimates. Without the use of a comprehensive survey, other techniques must be developed to provide a nighttime fishing estimate. Basically, the nighttime estimate is a proportional figure tied to the level of daytime activity. For example, if daytime catch is estimated at 100kg and the proportional nighttime rate is 25 percent, then the estimated night catch is 25kg.

At issue is identifying and selecting those procedures which will provide information concerning the relative size of the night proportion. A number of possibilities exist for obtaining the desired information. Attached to the catch/effort surveys could be a question concerning night fishing activity. The scope of the question could include not only the night activities of the intercepted fisherman, but also those of individuals known by the fisherman. Questions involving fishing method, location, size of catch, etc., could be asked. Another approach would be for the DAWR's conservation officers to keep a tally of night fishing during the officers' patrols. The use of the conservation officers in this manner could prove to be most valuable. Also, short-term surveys could be conducted by telephone or mail concerning night fishing. The list of subjective methods, i.e., asking "knowledgeable" individuals, is endless. The most productive method, however, appears to be utilizing the conservation officers and attaching night fishing questions to the existing surveys.

Illegal Fishing. Unfortunately, Guam is faced with a fairly significant illegal fishing problem, e.g., dynamiting and chlorinating, which over the long run could have a lasting destructive impact upon the inshore fishery. From a data collection point of view, however, the illegal fishing must be numerically estimated. The same proportional method used for night fishing is to be employed in developing an illegal fishing figure. The nature of the illegal fishing activity prohibits the use of traditional survey methods. Instead, qualitative methods must be undertaken to determine the desired proportional rate.

One possibility for assessing the illegal fishing activity would be to inform the populace through a public relations blitz. The public should be informed about the adverse impacts of illegal fishing. Their assistance should be solicited in reporting illegal activity to the DAWR conservation officers. All reports would be compiled to determine a measure of the activity. To assist in calculating the catch associated with the illegal fishing, the DAWR could estimate possible kill rates for particular illegal fishing activity. These estimates would take into account location, species prevalence, fishing method, etc. These figures would be used in assessing the illegal rate. Another alternative would be to ask fishermen about their knowledge of illegal fishing activity. The subject of illegal fishing is very sensitive; therefore, the sampler must take the necessary precautions to assure the fishermen of the desired information's purpose and

confidentiality. Also, questions on illegal fishing activities could be added to the catch/effort surveys. Finally, any information obtained by conservation officers involving illegal fishing should be transmitted to the fishery data collection personnel.

The problem of illegal fishing cannot be ignored by not incorporating the activity in the Island's catch estimates. Instead, the DAWR must experiment with different procedures for measuring the Island's illegal fishing activity.

THE SAMPLING ACTIVITY

This element of the FDCS deals with the support activities surrounding the actual implementation of the sampling design. In all, the sampling design proposed in the previous section requires five separate data collection activities: inshore fishing, offshore fishing, Merizo area fishing, night fishing, and illegal fishing. To successfully implement such a data collection system requires careful planning so that the sampler's efforts result in the collection of information which is of the desired quality, well-documented, and concisely maintained. The scope of the project does not include a detailed discussion of the necessary support procedures to insure the above result. However, a brief outline of the major procedures involved is provided as a guide to DAWR in its efforts to establish a complete FDCS.

Prior to conducting the actual survey operations, a number of preparatory steps must be undertaken. First, the theoretical structure of the sampling design must be formulated in terms of a series of detailed and well defined sampling precedures. The information presented in the sampling design section, coupled with DAWR's sampling knowledge, will provide the necessary information required to compile the list of sampling procedures.

All recording forms, i.e., questionnaires, tally sheet, sampler's log books, etc., must be properly constructed. The survey instruments currently being administered by the DAWR would serve as a basis for the set of recording forms. At any stage of the sampling program where information is being collected, the proper form must be in existence. In addition, sampler information gathered during the survey activity must be documented on the proper forms. This information will aid in the adjustment process and ongoing survey requirements.

A survey protocol packet should be developed and provided to each sampler. Items in the protocol should include at least the following:

- Sampler instruction manual, including a question-by-question discussion of questionnaire administration.
- Statement of purpose and background of the study
- Scheduling calendar
- Tide and moon phase calendar
- Special instructions and notes of unique circumstances of which the sampler should be aware

- Map of survey route
- Coding sheet
- Administrative requirements
- Sampler's log book

Each individual involved in one of the six survey procedures must thoroughly understand their specific sampling responsibilities as well as have a general knowledge of the program.

EXPANSION ALGORITHMS AND THEIR RELIABILITY

The expansion algorithm defines the mechanism for generating the desired numerical estimate from the survey results. However, survey results provide information only for the sampled fishing activity. In order to ultimately develop the desired Island-wide estimates, a series of equations are used to transform the survey data into its final form. The expansion methods can be viewed in terms of three general steps.

- Computations for daily catch estimates
- Computations for mean daily catch
- Computations for mean daily catch per month

The sample data is expanded as follows:

Computations for Daily Catch Estimates

- (1) First, calculate an estimate of total sampling period effort

$$e = n \times \bar{h}$$

where e = total effort expended during sampling period

n = number of fishermen (vessels) counted

$\bar{h}$ = average number of hours fished

Inshore and offshore total sampling period effort are calculated separately. Since the inshore survey primarily deals with incomplete trips $\bar{h}$ equals actual hours fished plus the additional expected hours to be fished. Equation (1) can be disaggregated by gear (or other variables) if desired. For example, Equation (1) becomes

$$(1)' \quad e_i = n_i \times \bar{h}_i$$

where, i = gear being used

therefore,

$$(1)'' \quad e = \sum_i e_i$$

- (2) Second, determine the estimate of total day effort

$$E = e / p_1 p_2$$

where,

E = total island effort for fishing day

p_1 = proportion of fishing activity occurring in a given sampling period

p_2 = Proportion of fishing activity occurring in a given region

Obviously, the key to Equation 2 is properly specifying p_1 and p_2 for both inshore and offshore activity. The disaggregation of Equation 2 by gear yields the following:

$$(2)' \quad E_i = C_i / p_1 p_2$$

if possible, the p_1 and p_2 variables should be gear specific therefore,

$$(2)'' \quad E = \sum E_i$$

- (3) Next, calculate the estimate of catch per unit of effort

$$CPE = \frac{B}{P}$$

where,

CPE = catch per unit of effort

B = total recorded weight of fish sampled

P = total measured pressure recorded during sampling, e.g., total number of actual hours fished.

The data for Equation (3) is supplied solely from the survey results. Equation (3) can be disaggregated by gear as follows:

$$3)' \quad CPE_i = \frac{B_i}{P_i}$$

therefore,

$$3)'' \quad CPE = \sum w_i CPE_i$$

where,

$$w_i = \frac{P_i}{\sum P_i} ; \sum P_i = P$$

- (4) The final calculation of this category is to estimate the total day catch

$$C = CPE \times E$$

where, C = total day catch.

Disaggregated by gear equation (4) becomes

$$4)' \quad C_i = CPE_i \times E_i$$

therefore,

$$4)'' \quad C = \sum C_i$$

Computations for Mean Daily Catch

The mean daily catch is determined for each stratum. For the case at hand, the allocation between WE/H and WD, represent separate strata.

- (5) The mean daily catch for each stratum is defined as

$$\bar{C}_{WD} = \sum_{\ell=1}^{n_{WD}} C_{WD,\ell} / n_{WD} ; \quad \bar{C}_{WE/H} = \sum_{\ell=1}^{n_{WE/H}} C_{WE/H,\ell} / n_{WE/H}$$

where,

$$\bar{C}_{WD}, \bar{C}_{WE/H} = \text{mean daily catch}$$

$$C_{WD,\ell}, C_{WE/H,\ell} = \text{estimated total day catch for } \ell\text{th day}$$

$$n_{WD} \quad n_{WE/H} = \text{number of days sampled}$$

Disaggregated by gear equation (5) becomes

$$5)' \quad \bar{C}_i = \sum_j C_{ij} / n_i$$

where, $\bar{C}_i$ = mean daily catch for i^{th} gear

C_{ij} = estimated total day catch for i^{th} gear
on j^{th} day

n_i = number of days sampled for i^{th} gear

therefore,

$$5)" \quad \bar{C}_{\text{WE/H}} \text{ or } \bar{C}_{\text{WD}} = \sum g_i \bar{C}_i$$

where,

$$g_i = \frac{n_i}{N}$$

N = total number of days sampled

Note: $\bar{C}_{\text{WD},i} = g_i \bar{C}_i$

The variance associated with the mean daily catch is defined as follows:

$$(6) \quad \text{Var} (\bar{C}_k) = \frac{\sum_{\ell=1}^{n_k} C_{k\ell}^2 - \left(\sum_{\ell=1}^{n_k} C_{k\ell} \right)^2 / n_k}{n_k - 1}$$

where,

k = the strata, i.e., WE/H, WD

n_k = the number of days sampled with the k^{th}
stratum, i.e., n_{WD} ; $n_{\text{WE/H}}$

Computations for Mean Daily Catch Per month

To calculate the mean daily catch per month, the following equation is used:

$$(7) \quad \bar{C}_d = \frac{N_{\text{WD}}}{N} \bar{C}_{\text{WD}} + \frac{N_{\text{WE/H}}}{N} \bar{C}_{\text{WE/H}}$$

where,

$\bar{C}_d$ = Mean daily catch per month

N_{WD} = Total number of WD in month

$N_{WE/H}$ = Total number of WE/H in month

N = Total number of days within month

Disaggregated by gear, equation (7) becomes

$$7)' \quad \bar{C}_{dk} = \frac{N_{WD}}{N} \bar{C}_{WD,i} + \frac{N_{WE/H}}{N} \bar{C}_{WE/H,i}$$

therefore,

$$7)'' \quad \bar{C}_d = \sum_i \bar{C}_{di}$$

The variance for the mean daily catch per month is defined as:

$$8) \quad \text{var.}(\bar{C}_d) = \sum_k W_k^2 \text{var}(\bar{C}_k) / n_k - \sum_k W_k \text{var}(\bar{C}_k) / N$$

where, W_k = the stratum weight (N_k/N)

The expansion system can account for the climatic impact on fishing activity in one of two ways. First, a sampling day could be used regardless of climate condition. Thus, changes in activity would already be accounted for in the survey results. Second, sampling could take place during "normal" climatic conditions only. Then, the value of N in the above equation can be adjusted according to the method currently in use by DAWR for the offshore survey. DAWR should also consider the option of conducting a study on how climate conditions affect fishing activity for both inshore and offshore activity.

The final steps in the expansion involve the following three steps:

- 9) The total harvest for the month ($\hat{c}$) equals $N \times \bar{C}_d$
- 10) The standard error of the total harvest (s) equals

$$N (\sqrt{\text{var} (\bar{C}_d)})$$
- 11) The 90 percent confidence limits for total harvest are

$$\hat{C} \pm t_{df} s.$$
The degrees of freedom (df) which determine the t value can be approximated using the number midway between the smallest value of $n_k - 1$ and $\sum n_k$.

It should be noted that the same sequence of calculations can be followed to estimate total effort or CPE by making the appropriate substitutions.

The above methods furnish catch estimates for inshore, offshore and Merizo. In order to derive a total Island-wide estimate, the night fishing and illegal fishing values must be factored in. Basically, these two variables enter as scalars in the computation procedures for the catch estimate objective.

PROCESSING THE SYSTEM'S DATA BASE

In general terms, as the survey work is completed, data processing procedures must be in place to insure that the final data set is accurate. These data processing procedures commence the moment a questionnaire is brought out of the field. Each questionnaire must be checked for completeness, consistency, and proper coding. Data from all questionnaires should be keypunched into a computer file as soon as possible

in order to minimize the possibility of misplacing the questionnaires. Of great importance at this stage of the data collection activity is the existence of clearly-stated procedures for processing the raw field data into the form and configuration of the final data set.

QUALITY ASSESSMENT METHODS

An essential part of the FDCS is a series of quality assessment (QA) procedures. These procedures act as checks to insure that the data being collected, processed and manipulated meet the desired quality levels. QA procedures can be classified into two groups: internal and external. Internal methods involve sampling procedure checks and data processing checks, while external methods entail comparing estimated results with data from independent sources. Together, these QA methods provide the insurance necessary to generate a useful and viable fishery data collection system.

Sampling procedure checks are QA efforts directed at the survey activity element of the system. These checks include reviewing sampler-specific survey results to uncover potential sampler bias and assessing and adjusting, when necessary, sampling allocation factors when new information is acquired. The FDCS calls for a number of data handling phases and with each handling, e.g., keypunching, the chance of error increases. The QA techniques are geared to evaluating if this additional

error is significant, and if so, to correct the problem. An example of such a technique is subsampling the data set and checking this sample with the original questionnaire. If the error rate from the sample is significantly higher than the desired rate, then the entire data set would have to be re-checked. This test boils down to a simple proportional statistical test. Additionally, more sophisticated procedures can be devised if required by the sampling program.

External methods provide a valuable means for assessing the reasonableness of the final fishing activity estimates. These external methods involve developing fishing estimates from independent sources. Such sources would include demographic data, other surveys, i.e., the recreational fishing survey, and other reports. For example, fishing participation estimates can be compared with population figures to determine if the relative sizes are reasonable. A fundamental part of the FDCS must be a well-defined QA program.

PRESENTATION OF THE FISHERY DATA COLLECTION SYSTEM

Careful consideration must be given to the FDCS's presentation format. The governing criteria in this area is whether or not the presentation format correctly reflects the information collected by the system, not only in terms of tables, but in the written text as well. The effective presentation of the FDCS depends, in part, on the reader of the report.

Together, these considerations will ensure that the FDCC is presented in a clear and concise manner.

SUMMARY

The proposed FDCC presented in this report focuses on two specific elements: the sampling design and expansion algorithm procedures. In developing this system, the unique structure of Guam's fishing environment and the data collection expertise of the DAWR were integrated into the design. Essentially, the sampling design is comprised of two survey approaches: statistical survey methods and qualitative inference methods.

Two statistical survey methods involved three separate survey procedures: offshore sample survey, inshore sample survey, and the Merizo area survey. The offshore and inshore sample survey furnish participation, catch and effort information. In addition, these two sample surveys collect information on length of fishing trip, species composition, gear, weather, and other variables. Finally, the Merizo area survey, which was not designed in specific terms, supplies fishing activity information for the Cocos Lagoon region of the Island.

To obtain estimates of fishing activity, i.e., night, illegal, not readily available by sample survey techniques, a series of qualitative methods were suggested. At the very least, these methods would generate information concerning the

level of night and illegal fishing. Basically, the qualitative methods involve collecting information using informal methods, i.e., conservation officers, as observers.

Data collected from these data-gathering activities provide the basis for the estimated total catch figures. Once the survey results are formalized during the data processing procedures, the total catch variables can be computed using the equations specified in the expansion algorithm section. The gear-specific average catch estimates derived for inshore and offshore activity are expanded by the total number of fishing days and the level of fishing participation for that time period. Adjustments for night and illegal fishing are factored into the equation as well. To assist in measuring the reliability of the total catch variable, its variance is derived. Confidence intervals can now be calculated for the total catch variable.

ABSTRACT

Hawaii's wholesale seafood market and its role in the development of the commercial fishing industry are described. The study extends previous analyses of seafood markets in Hawaii by including the market for frozen seafood and the import and export sectors.

Data from a 1980 National Marine Fisheries Service survey are presented on the flow of seafood through the wholesale market and cross tabulation statistics are used to examine economic relationships in the wholesale market.

The study concludes with a brief analysis of the interrelationships between key factors affecting the wholesale market and government policy directed toward commercial fisheries.

INTRODUCTION

This paper presents data and statistical analyses of data compiled by the National Marine Fisheries Service, Southwest Fisheries Center Honolulu Laboratory, on wholesale seafood markets in Hawaii. Historical information on seafood markets in Hawaii and theoretical considerations of competitive markets are also presented. The information from this research was used in another paper analyzing market exchange and competition under conditions of uncertainty.¹ The current paper provides a fuller description of the survey results and the general economic theory of market behavior underlying seafood exchange.

Hawaii's commercial fishing industry (including the fresh fish marketing system) remained virtually stagnant for the 15 years following statehood in 1959. A variety of constraints, including the structure of the fresh fish market, were blamed for the problems of the industry. Local fishers frequently complained about marketing arrangements, and many ways to circumvent these market channels were tried, including producer cooperatives, direct sales to consumers, bilateral negotiation with retailers (especially with restaurants and supermarkets), and forward integration by fishing companies into general seafood wholesaling and retailing. These arrangements have not proven to be adequate to promote sustained growth in the harvesting sector of Hawaii's seafood industry. The impediments to the expansion of local fisheries were outside the structure of the market, although the inertia of old marketing practices may have limited development. Alliances between individual harvesters and wholesale dealers which have broadened the wholesale market network and the growth of the auctions have had a major influence in recent expansion in the harvesting sector.

To understand why the wholesale market has been important to the growth of commercial fishing in Hawaii, one must examine those functions which contribute to industry development. This paper applies a theoretical framework to the characteristics of the wholesale fish marketing system in Hawaii as a means of providing an analytical description of that market.

Seafood Markets

Seafood markets are a particular type of business enterprise often called "intermediate trading agents" (Lim 1981). These enterprises serve a variety of functions in the interchange of products from producer to consumer (Plott and Uhl 1981). Fish dealers (brokers and wholesalers) are quintessential intermediate trading agents, taking on a variety of very specific functions in the diverse hierarchy of transactions in a product market characterized by minimal processing requirements.

¹Pooley, S. G. 1983. Competitive markets and bilateral exchange: The wholesale seafood market in Hawaii. Manuscr. in prep. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Seafood markets generally consist of two market forms: auctions for freshly harvested seafood and long-term contractual arrangements between harvester and dealer. Some auctions act to transfer seafood between brokers and wholesale dealers while others are the primary interface between the harvester and the retail sector. Hawaii has two harvester-wholesaler auctions which act as "spot markets," the market form most closely representing the economists' ideal where price is apparently determined in an open, competitive situation of many buyers and sellers.²

Two major types of contractual systems dominate bilateral transactions in the fishing industry (Wilson 1980). Reciprocal agreements represent purchases by dockside buyers where the price is offered by the buyer at the point of purchase. Consignment sales exist in markets where the catch is transferred to final markets and price is communicated to the harvester following sale. Reciprocal and consignment agreements represent individual transactions within the overall wholesale market, but these transactions are cut off from direct contact with other market actors, i.e., other commercial seafood harvesters and other dealers. Lacking immediate market information, the bilateral participants require a certain amount of trust upon which both the harvester and the wholesaler can depend. Relatively stable relationships are required for successful bilateral marketing of fresh fish but are difficult to maintain.

Reciprocal agreements are found in Hawaii when fishers bypass the auction either by dealing directly with wholesalers, retailers, restaurants, and supermarkets, or by selling directly to a processor such as the tuna cannery or dried fish companies. Consignment sales are less frequent at the harvester-wholesaler level but exist in the transfer of catch between islands and in the export market. Both the Hilo and Honolulu auctions incorporate aspects of consignment transactions, e.g., ex-post discounts for fish found to be of poor quality.

Whereas the implicit contractual aspect of the bilateral trading arrangements between harvester and marketer reduces individual inefficiencies and inequities which might otherwise arise where information is incomplete, Wilson (1980) found that such bilateral arrangements also tend to suppress the flow of information to the overall market and reduce the market's performance as an allocator of resources. Impediments range from inventory gluts and product wastage to poor quality and broken arrangements. Each impediment can be ascribed to the quality of bilateral exchanges. Wilson found that the "actors" in the New England seafood market respond (or "adapt") to these problems by avoiding "competitive" market behavior, i.e., by minimizing changes in buyer-seller patterns, minimizing price bidding, and maximizing inventory control through selective limitations on fishing effort. Thus, competition (in the economic as opposed to the social sense) is replaced by negotiation.

²The term "market" has two uses. In common terminology, it refers to places where many sellers are located, while for economists, markets denote the universe of exchange transactions at a particular level of aggregation.

Prices, which are the primary market signal available to consumers, become less informative and both harvesters and consumers suffer.

Although these factors are specific to the fresh fish markets studied by Wilson in New England, they are not unique. Similar evidence exists for Hawaii's seafood transactions (Peterson 1973; Garrod and Chong 1978). Adaptations to market imperfections effectively change the assumptions of analysis and might have significant implications for fisheries development in Hawaii.

A wide variety of market studies have emphasized the transactional aspects of exchange relationships (Coase 1937; Stigler 1961; Grossman and Stiglitz 1976; Figlewski 1978; Hirshleifer and Riley 1979). These aspects were frequently neglected by traditional microeconomic analysis of market behavior and prices. Important aspects of market transactions are their information bearing abilities, their risk assignability, and their responsiveness to uncertainty. The acquisition and consolidation of market information within the confines of the wholesale firm provide key avenues for economies of scale. Internal control of information acts as a barrier to other firms, much as do large initial investment costs (Wilson 1975). In seafood markets, fresh fish auctions act to pool price, quantity, and quality information because auction transactions are quasi-public. However, individual wholesale dealers have a strong incentive to obtain additional information and product outside the auction, as they have done in the import and export markets and through local bilateral arrangements. This reduces the risk and uncertainty besetting the firm, and it also limits the public availability of information on the firm's business practices. Thus, in Hawaii, wholesale fish dealers are combining several types of market transactions for specific marketing problems which are outlined in the following section.

Seafood markets contain a wide range of risk and uncertainty, including fluctuating supply, product spoilage, and product quality. Analysis of risk is directly applicable to the problems of inadequate quality premiums cited by Wilson (1980) in the bilateral agreements of the New England fish market. Furthermore, fishery markets regularly exhibit characteristics which strain the credence of the competitive model. Wilson's implication is that every transaction is subject to some form of imperfect competition because of its bilateral character. This pertains particularly to the small number of brokers and wholesalers in seafood markets compared with the many disparate and independent sellers on the other sides of the transactions, i.e., the individual fishers and retailers.

Yet, as will be shown in the concluding section, it is precisely the adaptability of some major wholesalers in Hawaii to imperfect marketing conditions which seems to have played a major role in the expansion of commercial fishing in Hawaii over the past 5 years. To understand this unexpected conclusion it is necessary to examine the theoretical determinants of competitive markets, to compare these with the reality of fish wholesaling in Hawaii, and to indicate how adaptations at the wholesale level have affected the entire commercial fishing industry.

The Theory of Competitive Markets

Markets do not in reality consist of atomistic competitors (i.e., small and totally independent firms), that prices are not abstractly determined by the disinterested interplay of such numerous competitors, and that resources are not solely allocated by reactions to price. Yet, these are the basic assumptions of microeconomic theory and provide the basis for normative prescriptions against monopoly, regulation, and economic planning.³ Although industrial economics traditionally studied market structure and the degree of competition, most policy analyses in the past 30 years have operated under the norm of relatively perfect competition (Friedman 1962). However, emphasis on other aspects of industrial structure is returning (Williamson 1981).

The structure of a market was thought to matter because of (1) its social welfare implications, (2) the impact of the market on productive efficiency, and (3) its influence on the distribution of income.⁴ Previous analysis of Hawaii's seafood market has not included welfare considerations because the lack of a thorough market description has limited an assessment of the impact of market structure on the economic behavior of individual dealers, commercial fishing firms, and seafood consumers. Although several analyses have pointed to possible imperfections in the seafood markets, public policy has generally assumed the salience of local markets ([Hawaii.] Department of Land and Natural Resources 1979).

The degree to which Hawaii's fish markets correspond to the competitive market provides an indication of how the wholesale sector must be analyzed. Basic microeconomic market structure assumptions as applied to Hawaii's seafood markets include:

1. Scarcity: Resources are assumed to be relatively scarce compared with consumer demand. Therefore, choice between alternative patterns of resource allocation is required.

In fish markets there frequently is a situation of abundance, indeed often of gluts, viz long-term price levels. The wholesale fish market serves to mediate these fluctuations in supply, but wide fluctuations in price levels are inadequate market signals for medium-term decision making. Nonetheless, because wholesalers have limited business resources, an additional scarcity problem exists at the marketing level, and this is important in their choice of product, product state, and product source and destination.

³The basic assumptions upon which microeconomic price (and thus market) theory operates are not well supported in any market setting (Franklin 1977).

⁴"Welfare" in the economic sense of overall good to society through competitive resource allocation, not as an income transfer term.

2. Large numbers: No individual market "actor" or small group of producers or buyers can significantly influence product price.

There are 118 wholesale seafood firms in Hawaii, about 100 full-time fishing enterprises, perhaps 2,000 part-time commercial fishers, and hundreds of retail outlets which handle seafood. Only the wholesale sector acts in a "small numbers" environment although harvesting cooperatives and financial consolidation may reduce the effective number of competitive harvesters for some species. One cannery purchases the dominant species (skipjack tuna), and a relatively small number of dealers engage in the majority of fresh and frozen seafood transactions. Therefore, this norm of competitive market theory is challenged.

3. Corporate mobility: Firms may freely enter and leave the industry.

Adams (1981) has documented entry and exit (turnover) in the wholesale fresh fish market in Honolulu and suggested that the industry is competitive when judged on this basis. The extent to which turnover is significant as a market indicator has been challenged (Hudgins 1980a) and ability to reallocate wholesale business resources would seem costly at any time. Furthermore, new firms face an information gap and a learning period in developing their buying and selling practices. Therefore, there may be problems of transition whenever the overall market grows. However, a diversity of firms exist to help maintain this norm.

4. Product homogeneity: All sources of a commodity are said to be interchangeable in the eyes of the consumer, i.e., they are essentially identical.

Agricultural commodity markets are frequently cited as models of competitive behavior because individual farm products appear to be relatively homogeneous. However, the wholesale seafood market discriminates between sources of seafood, i.e., differentiates local full-time commercial harvesters from part-time and transient harvesters. Furthermore, it is certain that the fresh and frozen fish markets are dichotomized precisely because consumers have definite, though possibly shifting, seafood preferences not completely related to price differentials. The product, "fish," is highly differentiated, although substitution among species and product may be relatively frequent. Elasticities of price and cross-elasticities of substitution have not yet been thoroughly calculated for seafood in Hawaii although Hudgins (1980a) made preliminary estimates and found relatively little substitution among major species groups. Thus, competition has an additional source of limitation in product heterogeneity.

5. Complete knowledge: All buyers and sellers have thorough knowledge of the market situation and their alternatives.

Hawaii is a very centralized state and 80% of the population live on one island (Oahu). If market knowledge on the local level is ever to be realized in the seafood industry, it should occur in Hawaii. However, the range of uncertainties which face wholesalers is considerable, even on the

local level. Knowledge about international and U.S. mainland market opportunities is seldom easily available. Institutional impediments to the flow of information through the seafood market may also reduce the knowledgability of market participants. Therefore, there is an information burden to seafood market transactions, particularly at the wholesale level.

6. Rational self-interest: Economic "actors" behave to maximize their returns, i.e., profits or personal utility.

In a competitive market system, failure to act "rationally," to minimize costs and to expand markets, usually leads to business failure. However, subsidiary factors which affect business decisions, such as tradition and kinship, may play important market roles in less competitive industries. The familial nature of the fish business in Hawaii suggests that "non-rational" behavior may exist in the market. Yet, profitability is essential in a private enterprise economy if wholesalers are to undertake risky ventures into new products or harvesting. The rate of turnover identified by Adams (1981) suggests that rational self-interest is essential for maintaining a market share in Hawaii's seafood industry.

7. Private ownership: Economic resources are privately owned and controlled.

The fishing industry in Hawaii operates in an essentially small business environment where corporate ownership and economic control coincide. The wholesale sector is typified by business decisions directly related to seafood markets. However, the cannery and some portions of the retail sector are examples of large corporate hierarchies where marketing decisions are not made solely on the conditions directly affecting the fishing industry. Nonetheless, it may be assumed that most marketing decisions are privately, and locally controlled.

These seven conditions are considered essential for preserving the microeconomic model where atomistic economic units are "harmonized" by competitive markets and exchange transactions force a form of social cooperation, i.e., the private allocation of resources on behalf of society. Microeconomic theory indicates that these conditions enhance private and social productivity and reduce the social power of individual industry participants (Friedman 1962). Failure to meet these and related conditions reduces the efficacy of the microeconomic model (Graff 1954).

The seafood industry in Hawaii meets these basic assumptions well, but not completely, and as such it may at least be termed "contestable" (Baumol 1982). The industry is neither vertically nor horizontally integrated in that harvesting, processing, wholesaling, and retailing operations are usually undertaken by separate firms. Most economic transactions occur in the marketplace, although the key market role of the wholesalers is the variety of marketing functions, such as transportation, insurance, and inventory, which they undertake within their individual firms. The level of transactions within the wholesale sector is quite specific and specialization occurs in product states and in source and destination orientations.

Of the seven basic assumptions of the competitive model, three may be said to be significantly challenged in Hawaii's wholesale markets: large numbers, product homogeneity, and complete knowledge. Such "deviations," however, do not imply monopolistic conditions in the market, nor intentional collusion. However, these deviations may affect market behavior and social welfare. These market characteristics can now be examined and their effect on market dynamics in the commercial fishing in Hawaii assessed.

A Profile of Hawaii's Seafood Market

The overall wholesale seafood market in Hawaii is much more diverse than even the folklore of the fresh fish market would suggest. Although this history has been well described (Peterson 1973; Garrod and Chong 1978; Adams 1981), fresh fish is but one part of Hawaii's seafood marketing system. The production of seafood sold in Hawaii is both an international and a local phenomenon. Markets exist for particular products based on strong cultural preferences and on the expectations of restaurateurs. Frozen seafood is important in domestic and tourist consumption (Hudgins 1980b) and export of locally caught fresh fish is expanding (Cooper and Pooley⁵).

Production in Hawaii's commercial fishery has long been dominated by the tuna fisheries, particularly that for skipjack tuna (aku). Past studies have thus dealt primarily with the pole-and-line fishery for skipjack tuna, the problems in that fishery, and the role of skipjack tuna in the Hawaii fresh fish market. Because there has been little growth in this segment of the market, the Hawaii commercial fishery and the fresh fish market had been described as stagnant.

Despite this, Hawaii's commercial fishery has expanded dramatically in the past 5 years, primarily due to fisheries for bottom fish and large tunas. Previous studies pointed to the lack of capital investment in large, far-ranging skipjack tuna and multipurpose fishing vessels as the "death knell" for Hawaii's commercial fishery. Ironically, it is the growth of a small boat fleet and the dramatic increase in its productivity which have led to recent market expansion. Using relatively simple techniques that require little capital investment, i.e., deep-sea handline methods, a major impediment to commercial fisheries expansion (capital costs) has temporarily been bypassed (Yuen 1979). More vessels are also utilizing fuel-efficient longline gear on a small scale and are fishing around fish aggregating devices (Shomura and Matsumoto 1982). Development of the fishery in the Northwestern Hawaiian Islands evidently is still limited by capital requirements but this fishery has also expanded.

The relatively high demand for the bottom fish and large tunas harvested by deep-sea handline attracts a large number of part-time and

⁵J. C. Cooper and S. G. Pooley. 1982. Total seafood volume in Hawaii's wholesale fish markets. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812. Admin. Rep. H-82-15. 12 p.

small-scale fishers to this market. A variety of non-traditional marketing arrangements have developed, and the fresh fish auctions have been rejuvenated. The commercial fishery's greatest expansion was not due to technological advances or marketing innovations in the dominant skipjack tuna fishery but due to a return to traditional methods in harvesting other species and the ability of local wholesale dealers to market this product. The effect of this competition within the skipjack tuna fishery has been significant. The frequently used term "tuna industry" in the Hawaii setting is definitely misleading. There is obviously a major difference between the two-tiered bilateral exchange skipjack tuna market where set portions are allocated to the fresh fish market and the cannery, and the ahi market (yellowfin and bigeye tunas) which is a fully competitive high-price fresh fish market. Indeed, the increased competition between aku and ahi in the fresh fish market emphasizes this difference in marketing practices. Increasing levels of substitution among the fresh fish market species is being witnessed. The analysis below reflects this heterogeneity. Further research on the retail market and renewed interest in market structure should provide a clearer indication of trends affecting the commercial fishery in Hawaii.

The Southwest Fisheries Center, Honolulu Laboratory surveyed the Hawaii wholesale fish dealers in 1980^{5,6} and again in 1982^{7,8} to assess the overall flow of seafood through Hawaii's seafood markets. As opposed to other studies, these surveys took into account not only locally caught fresh fish but also fresh imports and exports, frozen imports, and other forms of processed seafood products.

The 1980 sample frame consisted of 185 seafood marketing firms compiled from telephone directories and supplemented by direct knowledge of the industry. A total of 118 firms were actually engaged in the wholesale seafood business and 105 firms were successfully interviewed in July 1980. Data were collected for the 1979 calendar year. The characteristics of the average wholesale fish dealer and total wholesale seafood volume are outlined in Table 1.

The study emphasized product state (fresh, frozen, canned or bottled, etc.), source (local vessels, auctions, imports, etc.), and destinations (retail, export, processing, etc.) (Tables 2, 3 and Figs. 1, 2).

⁶U.S. National Marine Fisheries Service. 1982. Preliminary results of a survey of wholesale fish dealers in Hawaii. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, Admin. Rep. H-82-14, 17 p. + append.

⁷SMS Research, Inc. 1982. Survey of monthly prices and quantities of wholesale fish products in Hawaii: Final report, 39 p. + append.

⁸SMS Research Inc. 1983. Survey of the broker and retail fish sectors of the fish markets in Hawaii: Final report. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, Hawaii, Admin. Rept. H-83-10C, 45 p.

Table 1.--Characteristics of Hawaii's wholesale seafood market in 1979
(adapted from Cooper and Pooley, text footnote 5).

Category	Number	
Number identified	118 firms	
Number surveyed	105	
Additional types of business		
Retail	63 firms	
Processing	27	
Storage	15	
Type of product handled		
Fresh	63 firms	
Frozen	63	
Canned and bottled	17	
Salted, dried, and smoked	26	
Fishcake	13	
Percent business which is wholesale (average)	72.9%	
Average starting year	1960	
Employees		
Full-time paid	1,490 employees	
Part-time paid	618	
Full-time unpaid	33	
Part-time unpaid	3	
Market volume ¹	Value (million)	Pounds (million)
Total purchases	\$55.0	30.4
Fresh	25.7	12.7
Frozen	22.9	17.5
Other	6.4	0.2
Total sales	\$77.1	30.6
Fresh	32.7	13.8
Frozen	33.1	12.8
Other	11.3	4.8

¹These summary figures have been adjusted to replace missing observations. This may account for more pounds sold than purchased and indicates the reason for deviations from other tables.

Table 2.--Purchases by product and source in 1979
(Cooper and Pooley, text footnote 5).

Fresh

Local		
Fishers ¹	\$18,022,008	
Wholesalers	4,325,010	
Not specified	1,931	
Total		\$22,348,949
Imports		
Mainland	\$1,546,021	
Foreign	196,911	
Not specified	660,000	
Total		\$2,402,932
Total fresh		\$24,751,881

Frozen

Local		
Fishers ¹	\$23,080	
Wholesalers	465,284	
Total		\$488,364
Imports		
Mainland	\$13,133,950	
Foreign	8,019,095	
Total		✓ \$21,153,045
Total frozen		\$21,641,409
Canned and bottled		\$2,992,142
Salted, dried, and smoked		2,078,465
Fishcake		1,152,005
Total purchases ²		\$52,615,902

¹Includes auction fish.

²Totals are based on 99 firms.

Table 3.--Destination of products in 1979
(Cooper and Pooley, text footnote 5).

Local retail

Fresh	\$15,888,322	
Frozen	29,399,144	
Canned and bottled	4,504,577	
Salted, dried, and smoked	2,082,717	
Fishcake	2,239,619	
Total		\$54,114,379

Local processor

Fresh	\$725,174	
Frozen	72,291	
Canned and bottled	0	
Salted, dried, and smoked	0	
Fishcake	0	
Total		\$797,465

Local wholesale

Fresh	\$9,786,999	
Frozen	2,966,597	
Canned and bottled	73,722	
Salted, dried, and smoked	527,376	
Fishcake	76,400	
Total		\$13,431,094

Export

Fresh	\$5,288,697	
Frozen	61,861	
Canned and bottled	239,400	
Salted, dried, and smoked	0	
Fishcake	234,375	
Total		\$5,824,333

Total sales ¹		\$74,167,271
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¹Totals are based on 102 firms.

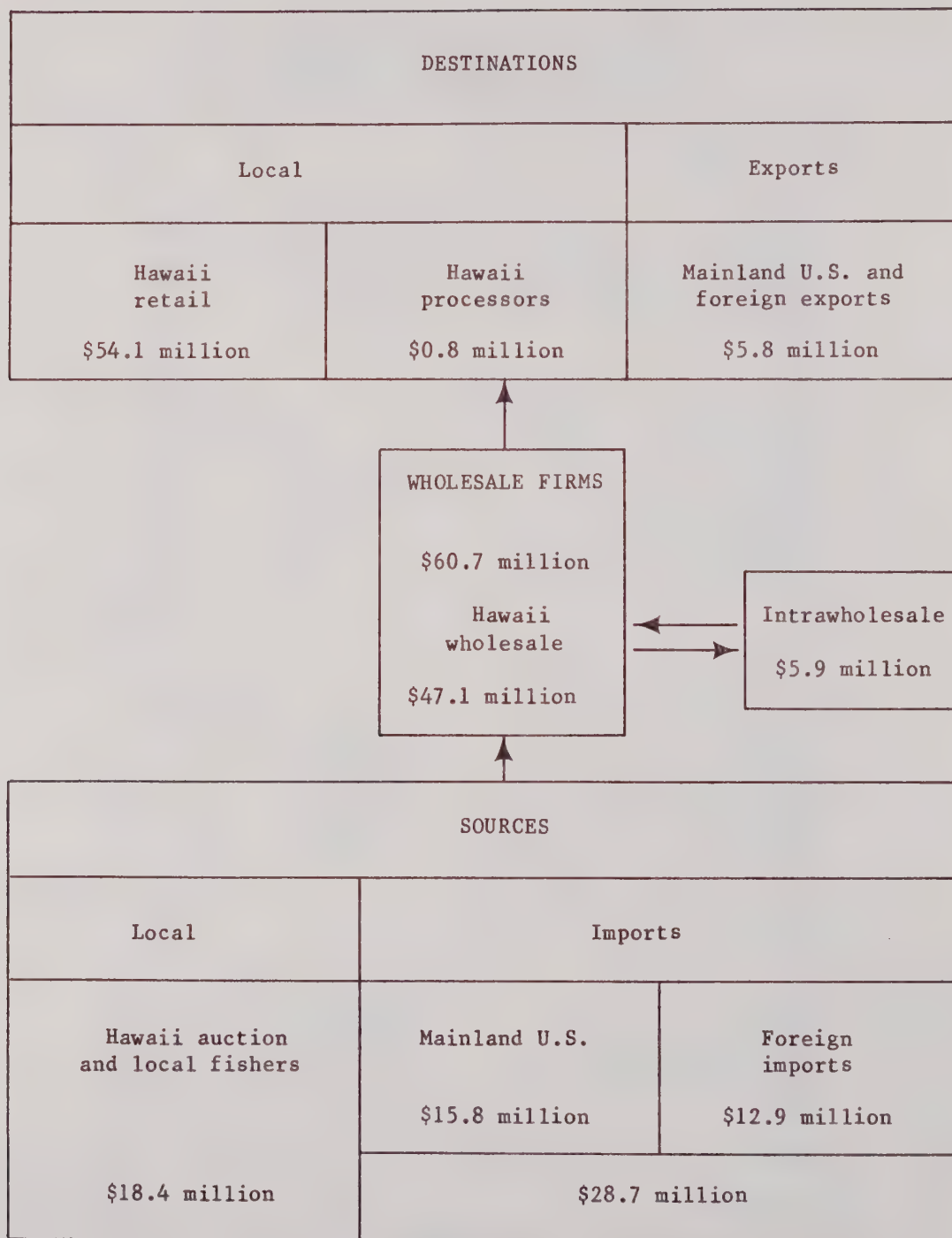


Figure 1.--Diagram of sources and destinations of seafood
(data from Cooper and Pooley, text footnote 5).

The wholesale market is fairly evenly divided between fresh and frozen products and most canned seafood products evidently bypass the wholesalers (Fig. 2).

Product State Sales		
Fresh	Frozen	Canned, dried, etc.
\$21.9 million	\$29.5 million	\$9.3 million

Figure 2.--Hawaii wholesale seafood sales in 1979 by products (data from Cooper and Pooley, text footnote 5).

Utilizing a variety of additional sources, we can make an overall estimate of the seafood market channels in Hawaii for 1979 (Figure 3). Production available for seafood markets was \$62.4 million in 1979, including \$24.3 million from local commercial fish and imported seafood. This seafood was then handled by wholesalers and local processors, and some was sold directly to retailers. Final retail sales are estimated at \$142.4 million, including domestic consumption of \$105.4 million (approximately \$101 per capita (24 lb)) and \$37.0 million in export, mostly processed or transshipped.

We believe that this is the first relatively comprehensive description of Hawaii's seafood marketing channels. Although imprecise and subject to revision as new data become available (especially for the retail sector), this description indicates the relative importance of frozen seafood imported from mainland and foreign sources to the overall supply of seafood in Hawaii, and thus to the behavior of businesses in the wholesale seafood market.

Assessment of Hawaii's Wholesale Seafood Market

Clearly there are a variety of analytical tools available to assess the performance of the wholesale seafood market in Hawaii. The approach we have chosen emphasizes statistical relationships of market structure, market channels, and market adaptation to risk and uncertainty.⁹ The first is explored primarily to respond to criticisms of monopolistic behavior in the market. The second is used to provide a coherent description of the

⁹Other methodologies include price and profit performance, location analysis, bargaining strategy and game theory, and comparative statics. These might be more appropriate for analysis of specific marketing problems, rather than for the overall descriptive and analytical purposes we have in mind.

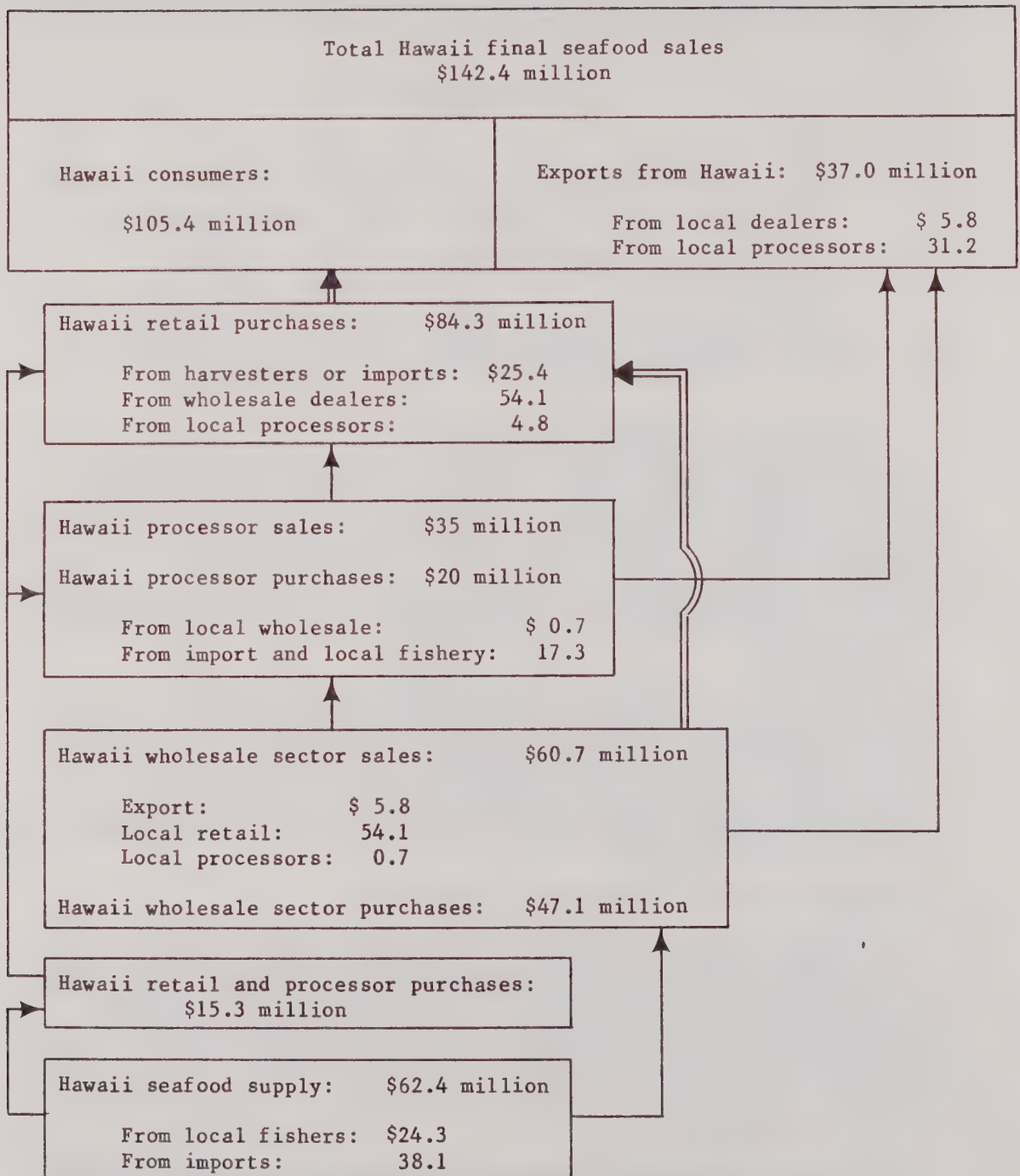


Figure 3.--Diagram on total seafood market flow in Hawaii, 1979
(in millions of dollars). (Sources available upon request.)

market's interrelationships. The third is employed to consider the role the wholesale market has in the development of the harvesting sector.

This section utilizes two-way contingency tables to depict the distribution of values for the major relationships and simple correlations pertaining to wholesale specialization in product state, source, and destination. Variables were stratified to provide a relatively uniform distribution of responses where no clear dichotomy existed for the boundaries in the contingency tables.

Frozen seafood is much more important in the wholesale market in Hawaii than had previously been emphasized. Frozen seafood provides 49% of sales from wholesalers to retailers. Fresh and frozen seafood are found in firms of all sizes, and there is a low correlation between firm size and proportional share of fresh or frozen seafood in a firm's wholesale revenue. The data on revenue from frozen (Table 4) and fresh seafood (Table 5) were stratified into percentages of total wholesale revenue for each firm. The chi-square statistics for these cross tabulations are significant but the simple correlation coefficients are not at a 90% confidence level.¹⁰ Interestingly, a subset of the sample which deletes firms that specialize 100% in frozen seafood provides a stronger positive correlation between firm size and share of revenue from frozen seafood (Table 6).

Because of the extensive frozen fish sales in Hawaii, it is possible to make many comparisons of the fresh and frozen sector which may reveal marketing practices. Previous studies and commentary on Hawaii's fresh fish markets have emphasized market imperfections which serve to limit competition. Economic theory suggests that if monopolistic behavior were a dominant factor in the fresh fish market and not a general market characteristic, price margins would be higher for fresh than frozen seafood. For firms specializing in fresh fish, at least for the larger firms which concentrate on wholesale transactions, this is not true. The margin on frozen seafood is slightly greater on average than that on fresh

¹⁰Chi-square indicates the degree which a sample population deviates from a proportional distribution of the values. Whereas the correlation coefficient is a linear relationship, chi-square emphasizes the distribution of values across the clarification variables. Although the variable range is arbitrary, major variables are stratified to maintain a relatively even distribution of total responses while maintaining a heuristically appealing differentiation of responses, dividing 0% and 100% revenue firms from the main sample where possible. The statistical proportions of the chi-square are not significantly affected by this choice. A nearly perfect 1/3-1/3-1/3 division variables across revenue and percentage frozen in Table 4 would give a chi-square of 7.57 ($P = 0.11$). Even stratification along the reference variables would be statistically unjustified and the results would be extremely skewed (95 "small" firms have sales revenue in the lower one-third).

Table 4.--Cross tabulation of firm size with share of revenue from frozen seafood sales.

Share from frozen ²	Firm size ¹			Total firms (\$748,946)
	Small	Medium	Large	
0%	22	15	3	40
1-99%	13	17	10	40
100%	5	12	3	20
Total firms (32.7%)	40	44	16	100
Chi-square: 9.35				df: 4
Simple correlation: 0.14				P: 0.05
				P: 0.18

¹Firm size categories were chosen by total wholesale seafood revenue: small = \$1 to \$99,999; medium = \$100,000 to \$999,999; and large = \$1 million and over. These size categories are used throughout the paper.

²As a percentage of a firm's wholesale revenue.

Table 5.--Cross tabulation of firm size with share of revenue from fresh seafood sales.

Share from fresh ¹	Firm size			Total firms (\$748,946)
	Small	Medium	Large	
0%	15	19	7	41
1-99%	8	17	7	32
100%	17	8	2	27
Total firms (49.8%)	40	44	16	100
Chi-square: 9.36				df: 4
Simple correlation: -0.07				P: 0.05
² N = 105				P: 0.47

¹As a percentage of a firm's wholesale revenue.

²Sample size is given for correlation when different from cross tabulation.

Table 6.--Firm size and share of revenue from frozen seafood for firms with less than 100% frozen product sales.

Share from frozen	Firm size			Total firms (\$744,378)
	Small	Medium	Large	
0%	22	15	3	40
1-99%	13	17	10	40
Total firms (15.8%)	35	32	13	80
Chi-square: 6.21 df: 2 P: 0.04				
Simple correlation: 0.26 P: 0.02				
N = 84				

seafood.¹¹ The overall wholesale margin is 48%, and the wholesale margin for fresh product is 41% and that for frozen product is 45% (Table 7).

There is a weak negative correlation between price margins and firm size and no correlation between overall wholesale margin and percentage of frozen seafood in total revenue (Table 7). The slightly larger frozen seafood margin does not necessarily imply higher profit rates in handling frozen seafood, since a variety of additional costs may be involved. It is not possible to make any inferences about profitability in the absence of cost and yield (loss from preparing seafood for further sale) information.

¹¹ Margins were calculated by comparing average purchase price and average sales price for a product (fresh, frozen, and processed). Because transfer of product between fresh and frozen can distort these figures, calculations were made by excluding firms which process seafood. Average prices calculated with changes in the form and composition of the product would create an additional source of error.

Table 7.--Fresh, frozen, and total wholesale margins for firms not engaged in processing (N = 79).

Price margins ¹			
Fresh	Frozen	Total wholesale ²	
41.4%	45.5%	48.4%	
Simple correlation of price margin with firm size:			
Fresh margin	r = -0.19	P = 0.27	N = 36
Frozen margin	r = -0.05	P = 0.78	N = 39
Total wholesale margin ²	r = -0.09	P = 0.48	

¹ Assumes no transfer between fresh and frozen product state by the wholesaler.

² Including trade in canned, dried, fishcake, and other processed products.

Hawaii is one of the few seafood markets in the U.S. which revolves around fresh fish auctions.¹² If manipulation of the auction were a dominant market characteristic, one might expect a positive relationship between firm size and participation in the auction and between participation in the auction and higher fresh fish margins. Again, this is not supported by the data. Although it is clear that small firms do not participate widely in the auction, the simple correlation coefficient between firm size and percentage use of the auctions is insignificant (but positive) (Table 8). Table 9 shows the cross-tabulation of auction participation and fresh fish price margin. There is no statistically significant relationship between these variables, although the simple correlation coefficient is negative. A negative correlation would be expected in the absence of collusion because of the presumed more competitive nature of auction transactions.

Seventy percent of the small firms dealing in fresh fish purchase no fish directly from the auctions, whereas 52% of the medium-sized firms and only 22% of the large firms purchase none of their fresh fish from the auctions. Seventeen percent of the firms buy over 50% of their fresh fish from the auctions, and 62% of auction fish is purchased by 4% of the total number of wholesale firms. However, calculating an "auction purchasing

¹²The auction form of market exchange is generally considered to be highly competitive, although this perception has been challenged for the Hawaii fresh fish market (Peterson 1973).

Table 8.--Firm size and use of auction for firms handling fresh fish.

Use of auction ¹	Firm size			Total firms (\$700,666)
	Small	Medium	Large	
0%	18	14	2	34
1-100%	7	11	7	25
Total firms (25.2%)	25	25	9	59
Chi-square: 6.76 df: 2 P: 0.03				
Simple correlation: 0.147 P: 0.27				

¹As a percentage of a firm's fresh fish purchases.

Table 9.-- Cross tabulation of use of auction with fresh margin for firms handling fresh fish.

Use of auction	Fresh margin		Total (36.5%)
	<25%	>25%	
0%	14	11	25
1-100%	14	10	24
Total firms (25.2%)	28	21	49
Chi-square: 0.027 df: 7 P: 0.87			
Simple correlation: -0.17 P: 0.23			

concentration coefficient" which measures purchasing dominance provides an intermediate value, 34.9%.¹³ Although medium-sized and larger firms have a relatively larger participation in the auctions as revealed in the chi-square statistic, neither price margin nor auction participation data support a conclusion of market collusion in the fresh fish market.

¹³Concentration coefficients are calculated from industry shares (Table 10). In this case, the shares are each participating firm's share of total auction sales. (Data is from unpublished NMFS sources.)

Table 10.--Concentration ratios.

	Industry-wide		Fresh product firms		Frozen product firms	
	C	N	C	N	C	N
Total sales	22	100	31	56	31	58
Fresh sales	31	58	31	58	45	34
Frozen sales	32	34	70	34	35	34

Industry-wide columns include the entire range of 105 firms. Fresh product columns indicate firms with over 50% of their wholesale revenue from fresh seafood sales. Frozen product columns indicate firms with over 50% of their wholesale revenue from frozen seafood sales.

The concentration ratio is calculated in the following manner:

Let C define the concentration coefficient of a sector of the industry.

Let R define the total wholesale revenue from that sector.

Let r_i define the revenue of the individual firm.

Let N define the number of firms in that sector of the industry.

Then C is calculated:

$$C = 100 \times \left[\left(\sum_{i=1}^N (r_i/R)^2 \right) \right]^{1/2} .$$

Overall, industry-wide concentration for the wholesale market, as well as ratios calculated for firms concentrated in fresh and frozen seafood separately, is minimal.¹⁴ Industry concentration is 22% from a possible range of 14-100% with only marginal increases, in most cases, when stratified by product state. This is not to say that the larger firms do not play a large role in the industry: eight wholesale firms account for over 50% of product sales (Table 11). Nonetheless, the issue of "small numbers" does not seem to play a central role in the competitive posture of Hawaii's overall seafood market.

Table 11.--Market shares of largest four and largest eight firms.

	Share	
	Top 4	Top 8
All wholesale	35.5%	53.5%
Fresh firms	52.8%	71.9%
Frozen firms	52.8%	75.4%

We can make a further analysis in this direction by examining the tendency of firms to specialize in particular product groups (species groups). Table 12 reports two types of specialization: within-firm and industry-wide species concentration.

¹⁴Concentration within industrial structures has been measured in a variety of ways (Rosenbluth 1955; Adelman 1958; Kakwani and Podder 1973). The approach we have taken is to calculate a summary measure of concentration which takes into account all the information available about the firms revenue patterns through use of the Gini-Herfindahl-Hirschman concentration coefficient which is related to the more familiar Lorenz curve approach to measuring income distributions. The measure is computed from the square root of the sum of the squares of the relative shares of each firm in the industry (Table 10). An alternative measure is also presented based on the market share of the largest four and eight firms in each market segment (Table 11).

Table 12.--Species concentration ratios.

Within-firm species concentration ratios (CISPP)							
Industry average: 74.4				Standard deviation: 19.8			
Theoretical minimum: 28.9				Range: 40.0 to 100.0			
N = 103							
Industry-wide species concentration ratios (CSP)							
N	Species	CSP	Share (%)	N	Species	CSP	Share (%)
44	Tuna	33	27.1	18	Akule	41	1.3
23	Ono	40	1.8	25	Mollusks	42	7.7
40	Bottom fish	40	18.6	16	Billfish	56	3.3
32	Crustaceans	40	11.5	4	Sharks	66	0.1
23	Reef fish	40	1.9	12	Opelu	66	1.2
42	Mahimahi	40	14.3	39	Other	37	11.6

The within-firm species concentration ratios (CISPP) is calculated for each firm analogously to the previous concentration measure (C). It is based on the relative weight of each species group (12 in total) in a particular firm's total wholesale revenue and is calculated for each firm. The industry-wide species concentration ratios (CSP) is calculated by each firm's percentage of that particular species group's share of the firm's total wholesale revenue, calculated over all firms.

The average CISPP indicate a relatively high average level of specialization (as compared with the industry-wide measure of revenue concentration) but a fairly wide range. Sixteen firms specialize totally (CISPP = 100) in one product group alone. Not surprisingly, within the frozen product segment of the industry, fresh fish sales are rather concentrated (indicating that most firms specializing in frozen product are unlikely to carry quantities of fresh product), and the converse is true for fresh product firms (figures not reported). The largest industry-wide participation is in locally important species (tunas, mahimahi, and bottom fish) whereas primarily frozen products such as crustaceans and mollusks have fewer traders than one might anticipate. This situation may be due to direct purchases of these frozen products by major retailers (e.g., supermarkets) from the mainland U.S. and from import brokers bypassing the wholesale sector and this survey.

We would expect larger firms to be more diversified in product groups (smaller CISPP) and cross tabulation of CISPP on firm size verifies this belief (Table 13). The chi-square statistic is significant at the 90% level of confidence, and although the simple correlation coefficient is not significant, the sign is correct.

Table 13.--Species concentration and firm size.

CISPP	Firm size			Total firms (\$748,946)
	Small	Medium	Large	
Below average	23	15	10	51
Above average	17	28	6	52
Total firms (74.4%)	40	43	16	103
Chi-square: 6.82		df: 3	P: 0.07	
Simple correlation: -0.10			P: 0.29	

Questions of monopolistic influences in the fresh fish market can be reexamined in light of product specialization. Domination within the fresh fish market for particular species can be seen by comparing the concentration ratio for auction purchases as a whole with purchases of individual species. Different firms dominate particular species, relating to their specialization in wholesale functions. Adams (1981) reported that eight wholesale buyers purchased 71% of fresh tuna, eight purchased 83% of fresh bottom fish, and eight purchased 67% of all species combined in the fresh fish market on Oahu in 1977.¹⁵ However, 81% of the firms in the Oahu fresh fish market handled tuna and 45% handled bottom fish. When including the frozen sector, only 43% of the firms handled tuna, 41% mahimahi, 39% bottom fish, and on down through the species groups listed in Table 12. Thus the existence of the frozen market suggests a higher level of specialization and a lower degree of concentration than when viewing the market solely from the fresh fish market perspective. There is essentially no difference in the relationship between species concentration ratios (CISPP) for the market as a whole and the fresh fish firms which utilize the auction (Table 14).

¹⁵These eight firms are not necessarily the same eight for each category.

Table 14.--Species concentration and use of auction for firms handling fresh fish.

CISPP	Use of auction			Total
	0%	1-99%	100%	(25.2%)
Below average	19	8	3	30
Above average	17	12	3	32
Total firms (76.6%)	36	20	6	62
Chi-square: 0.847		df: 2	P: 0.65	
Simple correlation: -0.059			P: 0.65	

There is a positive relation between firm size and the weight of wholesale trade in a firm's business as might be expected (Table 15). Large fish dealers can specialize in wholesale transactions without resorting to significant retail or processing trade to increase their scope of operations. However, because of the unusual problems of risk and uncertainty in the seafood industry, specialization by wholesale firms might lead to greater chances for catastrophic losses. The uncertainty of supply in fresh fish may be balanced with frozen food imports for major fresh fish dealers. Those firms doing a higher percentage of wholesale trade (as compared with wholesale and retail or processing) have a lower specialization in fresh product (Table 16).

Firm size is also important in intrawholesale trade. In the fresh market over 56% of the small firms sell no fish to other wholesalers compared with 32.4% of the medium and large firms. However no such ready identification can be made in the frozen product market as might also be expected (figures incorporated in Tables 17-19 but not reported). There is a strong positive correlation between fresh market specialization and purchases of seafood from other wholesalers (Table 18) reflecting the role of larger wholesale firms in auctions and direct purchases (bilateral exchange), whereas the reverse is true for frozen product (Table 19). We believe the latter relationship relates to the role of frozen product firms in filling special needs of fresh fish dealers.

Diversification of product source through foreign and mainland U.S. imports is a common practice for local seafood wholesalers. Fifty-five firms purchase from overseas to effectively reduce the uncertainty associated with seafood supply (Table 20). On the other hand, only 12 firms sell seafood abroad and these are strongly correlated with size of firm (Table 21).

Table 15.--Wholesale business and firm size.

Wholesale business ¹	Firm size			Total (\$748,916)
	Small	Medium	Large	
1-50%	19	6	0	25
50-99%	13	20	7	40
100%	8	18	9	35
Total firms (72.99%)	40	44	16	100
Chi-square: 20.39 df: 4 P: 0.000				
Simple correlation: 0.275 P: 0.006				

¹Measured as percentage of a firm's total revenue (including retail and processing).

Table 16.--Wholesale business and share of revenue for fresh seafood.

Wholesale business	Fresh share			Total (49.8%)
	0%	1-99%	100%	
1-50%	3	10	14	27
50-99%	15	14	11	40
100%	24	10	4	38
Total firms (72.9%)	42	34	29	105
Chi-square: 21.248 df: 4 P: 0.000				
Simple correlation: -0.427 P: 0.000				

Table 17.--Firm size and share of purchases from other wholesalers.

Purchases from other whole- salers ¹	Firm size			Total (\$748,946)
	Small	Medium	Large	
0%	31	32	7	70
1-10%	1	4	1	6
Over 10%	6	7	5	18
Total firms (8.6%)	38	43	13	94
Chi-square: 5.388 df: 4 P: 0.2497				
Simple correlation: 0.011 P: 0.915				

¹Given as the percentage of a firm's total wholesale revenue.

Table 18.--Intrawholesale purchases and share of revenue from fresh seafood.

Purchases from other wholesalers	Fresh share			Total (49.8%)
	0%	1-99%	100%	
0%	38	17	16	71
1-10%	1	2	3	6
Over 10%	0	12	6	18
Total firms (8.6%)	39	31	25	95
Chi-square: 20.982 df: 4 P: 0.003				
Simple correlation: 0.339 P: 0.001				

Table 19.--Intrawholesale purchases and share of revenue from frozen seafood.

Purchases from other wholesalers	Frozen share			Total (32.7%)
	0%	1-99%	100%	
0%	27	26	18	71
1-10%	3	2	1	6
Over 10%	8	10	0	18
Total firms (8.6%)	38	38	19	95
Chi-square: 6.317 df: 4 P: 0.177				
Simple correlation: -0.242 P: 0.018				

Table 20.--Firm size and import share.

Import share ¹	Firm size			Total
	Small	Medium	Large	
0%	14	9	2	25
1-50%	1	10	4	15
51-100%	18	17	6	41
Total firms (50.9%)	33	36	12	81
Chi-square: 10.16 df: 4 P: 0.04				
Simple correlation: 0.02 P: 0.88				
N = 105				

¹As measured by percentage of a firm's total wholesale purchases.

Table 21.--Firm size and export share.

Export share ¹	Firm size			Total
	Small	Medium	Large	
0%	35	31	8	74
1-100%	0	6	6	12
Total firms (2.8%)	35	37	14	86
Chi-square: 15.58		df: 2	P: 0.00	
Simple correlation: 0.26			P: 0.02	

¹As measured by percentage of a firm's total wholesale revenue.

The possibility of fisheries development in frozen fillet product lines has been broached for several years in Hawaii, and certainly there is a diversified market for frozen product. Whether domestic frozen bottom fish and groundfish can compete with mainland and foreign fillets is the key marketing question for these fisheries. Market diversity at the level is important for overcoming sales barriers and is a key factor in expanding the "economies of scope" (Panzor and Willig 1981) of wholesale firms. The combination of fresh and frozen product state in larger wholesale firms and the ability of the larger firms to experiment with forms of processing and handling provides diversity in both the wholesale and commercial fishing sectors.

CONCLUSION

This paper attempted to provide a systematic description of the markets for seafood in Hawaii based on an extensive survey of the wholesale sector. We identified three market factors which economic theory could identify as potential barriers to competition and efficient market behavior: small numbers, product heterogeneity, and an inadequate flow of market information. In addition, there are a number of general characteristics which affect Hawaii's seafood market and in which the specific characteristics of individual firms find their place. These general characteristics include:

Consumption: Hawaii's high per capita consumption of seafood estimated at 24 lb per capita and a large tourist industry (10% of de facto population) provide a relatively strong local market for seafood, especially fresh fish.

Domestic market: Despite the high per capita consumption, total demand is limited by population size (1 million residents, 4 million

tourists annually). The domestic market thus places significant constraints on the size of firms operating in Hawaii's seafood market.

Market coherence: Hawaii is an extremely centralized state with ready transportation between most locations (both production and consumption). This provides few economies of scale for the domestic distribution of seafood and makes domestic market information widely available amongst participants.

Location: Hawaii's geographical isolation makes transfers of product from outside sources of supply (imports) and to U.S. and other overseas markets (exports) costly, and information about mainland U.S. suppliers and buyers even more difficult to obtain.

Harvesting sector: Hawaii's commercial fishing fleet is characterized by individually owned, small-scale producing units. The wholesale sector faces a predominately competitive production sector and thus could act as a monopsonist (single buyer). However, in the harvesting sector there are sufficient differences between product specialties such that production of individual species (except tuna) can be affected by a small number of producers, or by producers in just a few locations (in the example of tuna). To a degree, elements of bilateral duopoly exist in the Hawaii market.

Retail sector: Hawaii has nine major supermarket chains which dominate home sales and the restaurant sector is also somewhat concentrated (through hotel chains). Thus the importation of frozen seafood in bulk by local seafood wholesalers is necessary for competitiveness in the wholesale sector as it faces the retail sector.

Corporate organization: Most seafood dealers (especially those specializing in fresh fish) and producers in Hawaii are family firms of limited capitalization. Horizontal integration into other food lines and vertical integration into harvesting are limited.

Tradition: Traditional bonds between wholesalers and individual fishers and between wholesalers and individual retailers are important in Hawaii. These long-time relationships can strain the wholesaler's capacity to respond to market conditions (e.g., accounts receivable) during periods of economic stress. However, they also make an important social contribution to the local fishery.

Collectively, these characteristics do not appear to impose significant market imperfections. Although various barriers to entry exist within this seafood market, these are primarily informal and specific to the tasks of wholesalers. The overall market requires that wholesalers act competitively. Transactions and information costs are high for the export market but this is simply Hawaii's comparative disadvantage, not a market failure.

The market analysis provided in the previous section suggests that the problems of limited numbers of dealers and of product heterogeneity are

also insignificant market imperfections. However, the various accounts of market power are not without foundation either, since large wholesalers predominate in most product lines. Thus the market can act to restrict some forms of competition. We would suggest that the market is somewhat oligopsonistic (i.e., limited competition in purchasing) but highly competitive when facing the retail market. This means that a few dealers play a major role in nonprice competition (e.g., preferential access to supply) but that sales price competition is significant. From the consumer's viewpoint, this suggests that day-to-day product availability may be affected by harvesters' attempts to maximize their market power (through limiting supply to increase a fishing trip's market share) but that product price is basically competitive despite occasional seasonal peaks. From the fishers' viewpoint, the market produces relatively good prices, but total revenue is rationed, often through bilateral arrangements and the fear of gluts at the auctions. This latter point is in accord with the findings of Wilson (1980) on the New England seafood markets. Commercial fishers face costs (price and nonprice) whether they participate in the auctions or bypass the auctions by using bilateral arrangements.

In terms of market information and transactions efficiency, the local fresh fish market appears to meet most of the competitive norms and standards. Information on price and quantity is effectively pooled through the auctions and a large number of such transactions are available for public inspection. While the harvesting sector of Hawaii's fishery was relatively stagnant in the 1960's and 1970's, the auctions were blamed for depressing prices. There were rational reasons in believing this but also in believing that the auctions (i.e., the major wholesalers) were simply dampening price fluctuations in the face of uncertainty and low demand. Now with the explosion of handline fisheries for tuna (especially yellowfin and bigeye), and the growth of bilateral trade, the auctions provide important information on the status of the domestic market. With the opening of export channels by some individual fishers (and wholesalers who buy directly from specific fishers) and the growth of the tourism market for fresh fish, the producers are now probably able to gain a relatively high value for their product, while the wholesalers, especially those with limited export capabilities, may be bearing the weight of market uncertainty and risk. This will not completely reduce the perception by the commercial harvesters that major wholesalers still manipulate the market, but problems of market development are significant to the wholesalers and to the harvesters. Because of the public nature of Hawaii's auctions, there appears to be no need for a local "market news" to communicate fresh fish marketing conditions although more timely ex post information might be useful.

There is probably less informational efficiency for frozen product imports and for export opportunities which are based on bilateral agreements. The potential may exist for a cooperative marketing association of harvesters and dealers, as has been promoted for various diversified agricultural and manufactured products in Hawaii. Similarly, because wholesale firms may play a major role in the development of the local commercial fishery, status reports on marketing conditions would be relevant to fisheries management plans and development policy. This way

some of the market information which is generally not viewed as a public commodity could be available for policy determinations.

Finally, in terms of the wholesale market's role in pooling and assessing uncertainty and risk, fishery management or development policy which tends to stabilize supply would tend to reduce wholesale costs, and vice versa. An additional source of supply-related risk in the Hawaii seafood industry is product quality, natural toxicity of some bottom fish and imported shrimp and mahimahi, deterioration of high-priced tuna, and spoilage of canned fish products. Management policy might also be directed toward reducing the chances for naturally occurring toxicity or developing projects to reduce the time required for seafood inspections. Collectively these actions would reduce not only the direct costs of losses by spoiled product, but also reduce the costs associated with "self-insuring" against such risks.

Wholesalers have an information handling burden based on complicated inventory problems. With highly valued product and expansion into the hotel and export sectors, failure to control information could be disastrous for dealers. Unfortunately these small businesses frequently lack the financial and organizational resources for computerized book-keeping and inventory control. A business resource, whether through an industry body or with government cooperation, might be the shared use of microcomputer and telecommunications facilities. This would serve the informational functions of the wholesale firms and improve the informational efficiency of the market. The possibilities for computerized communications and networks are unlimited although notions of antitrust may slow their cooperative deployment.

In conclusion, the general social welfare implications from this largely deductive analysis suggest that Hawaii's wholesale markets are operating efficiently. The availability of fresh seafood seems to be increasing, and high quality fresh seafood is certainly more widely available at the restaurant level. Price fluctuations appear to be dampening although fresh fish prices are still high. New opportunities exist for commercial fisheries development, assisted by the wholesale market sector. Other social problems of the seafood industry (e.g., employment effects) have yet to be analyzed but to do so would raise questions about the overall trajectory of Hawaii's economy. With a declining agricultural sector and a cyclical, and perhaps socially divisive, tourist industry, the seafood marketing industry would appear to be quite responsive to community needs.

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**CHARACTERISTICS OF HAWAII'S
WHOLESALE SEAFOOD MARKET**

By

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October 1983

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ECOPATH: A USER'S MANUAL AND PROGRAM LISTINGS

JEFFREY J. POLOVINA and MARK D. OW
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ADMINISTRATIVE REPORT H-83-23

INTRODUCTION

Recent trends in ecosystem modeling have produced complex simulation models which are very data intensive (Andersen and Ursin 1977; Laevastu and Larkins 1981). However, in many situations the construction of a biomass budget for a box model of an ecosystem is relatively simple and can provide important information about the ecosystem standing stock and energy flow (Walsh 1981; Pauly 1982; Polovina in press).

The ECOPATH model is an analytical procedure to estimate a biomass budget for a box model of an ecosystem given inputs which specify the components of the ecosystem, together with their mortality, diet, and energetics value. A computer program for ECOPATH has been written in BASIC-80, version 5.21, by Microsoft¹ (CP/M version) and a listing is provided in Appendix I.

The ECOPATH model produces estimates of mean annual biomass, annual biomass production, and annual biomass consumption for each of the user specified species groups. The species groups represent aggregations of species with similar diet and life history characteristics and which have a common physical habitat. The ECOPATH model is not a simulation model with a time component as are some more complex ecosystem models. It estimates a biomass budget for the marine ecosystem in a static situation under the assumption that the ecosystem is at equilibrium conditions.

Equilibrium conditions are defined to exist when the mean annual biomass for each species group does not change from year to year. This condition results in a system of biomass budget equations which, for species group i , can be expressed as:

- (1) Production of biomass for species i - all predation
 on species i - nonpredatory biomass mortality for
 species i - fishery catch for species i = 0 for all i .

The ECOPATH model expresses each term in the budget equation as a linear function of the unknown mean annual biomasses (B_i 's) so the resulting biomass budget equations become a system of simultaneous equations linear in the B_i 's. The mean annual biomass estimates are obtained by solving the system of simultaneous linear equations.

The formulation of each term of the biomass budget equation will now be presented in detail.

¹Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

THE MODEL

Biomass Production

Production (P) for a cohort of animals over 1 year is defined as:

$$P = \int_0^1 N_t \frac{d}{dt} (w_t) dt$$

and mean annual biomass (B) for the cohort is defined as:

$$B = \int_0^1 N_t w_t dt$$

where N_t is the number of animals and w_t the mean individual weight at time t .

Allen (1971) has investigated the production to biomass (P/B) ratio for a cohort over a range of mortality and growth functions. For a number of growth and mortality functions, including negative exponential mortality and von Bertalanffy growth, the ratio of annual production to mean biomass for a cohort is the annual instantaneous total mortality (Z_i). For a species group which consists of n cohorts or species, with instantaneous annual total mortality (Z_i) for cohort or species i , where mortality is determined by a negative exponential function and growth by a von Bertalanffy growth function, the total species group production (P) is the sum of the cohort production (P_i) and can be expressed as:

$$(2) \quad P = \sum_{i=1}^n P_i = \sum_{i=1}^n Z_i B_i$$

Under the assumption that the Z_i 's are all equal to say Z , then total species group production can be expressed as:

$$P = Z B$$

where B is the mean annual species group biomass.

Allen (1971) has also shown that when growth in weight is linear, the P/B ratio is equal to the reciprocal of the mean age for a range of mortality functions. For a number of other growth and mortality functions the ratio of cohort P/B can be the reciprocal of the mean lifespan. Thus, for a range of growth and mortality functions, total species group production can be expressed as:

$$P = C \cdot B$$

where B is the mean annual species group biomass, and C is a parameter. In an application of ECOPATH to an ecosystem of French Frigate Shoals where there was very little fishing mortality, the P/B ratio for fishes and crustaceans was taken as the annual instantaneous natural mortality (M); whereas, for primary and secondary producers whose growth is more likely to be linear than the von Bertalanffy, the P/B ratio was estimated as the reciprocal of the mean age (Polovina in press).

Predation Mortality

The predation mortality is the fraction of the biomass of a species group which is consumed by all predators. Two types of information are needed. First the food web or predator-prey relationships must be defined. A diet composition matrix DC_{ij} must be specified where an entry DC_{ij} from this matrix refers to the proportion (by weight) of prey j in the diet of predator i . The primary source of this information is the analysis of stomach contents (Macdonald and Green 1983). The second type of information needed to ascertain predation mortality is the food requirements of the predator. The ECOPATH model requires the user to specify FR_i , the ratio of annual consumption to mean annual biomass. The annual food required by the predator is the product of FR_i and B_i .

Some values of daily food required as a fraction of body weight range from 0.005 to 0.02 (Laevastu and Larkins 1981). Based on these daily estimates a range of annual food required as a fraction of mean biomass (FR_i) is 1.8 to 7.3.

Nonpredation Mortality

All mortality attributable to causes other than predation and fishing is termed nonpredator mortality. The ECOPATH model defines ecotrophic efficiency e_i as the fraction of total production which is removed by fishing and predation mortality. This was 0.95 in the French Frigate Shoals model. The nonpredator mortality rate is $(1-e_i) \cdot Z_i$, and the amount of production which goes to nonpredation mortality is

$$(1-e_i) P_i = (1-e_i) C_i B_i \quad .$$

For n species groups the biomass budget equation (1) becomes a system of n simultaneous equations as follows:

$$C_1 B_1 - \sum_{k=1}^n (FR_k) B_k DC_{k1} - (1-e_1) C_1 B_1 = \text{catch}_1 \quad ,$$

$$\begin{array}{cccc} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{array}$$

$$C_i B_i - \sum_{k=1}^n (FR_k) B_k DC_{ki} - (1-e_i) C_i B_i = \text{catch}_i \quad ,$$

$$\begin{array}{cccc} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{array}$$

$$C_n B_n - \sum_{k=1}^n (FR_k) B_k DC_{kn} - (1-e_n) C_n B_n = \text{catch}_n \quad .$$

With input estimates for parameters C_i , FR_i , DC_{ij} , and e_i for all i and j , and catches (catch_i) if there is fishing, this system of equations is a system of n simultaneous equations linear in the unknown B_i 's. This system of equations can be expressed in matrix form as $AB = C$, where A is an $n \times n$ matrix of coefficient, B is an n -dimensional vector of mean annual species group biomass, and C is the vector of fishery catch where the i^{th} element is the total catch for the i^{th} species group.

If the matrix A is of full rank and if there are some fishery catches for some species so the vector C is not null, then there typically exists a unique nontrivial solution vector of biomass B . If there are no fishery catches then it is necessary to provide an estimate of at least one of the mean species group biomass B_i before there exists a unique nontrivial biomass vector B which solves the budget equation. In the application of ECOPATH to an ecosystem at French Frigate Shoals where there was no fishing mortality, the biomasses of three apex predators were estimated from field censuses and treated as known inputs. In this application the i^{th} element of C vector was the annual predation by the three apex predators on the i^{th} species group.

THE COMPUTER PROGRAM

The ECOPATH model has been implemented via two BASIC language programs. The "dialect" of the language used is BASIC-80, version 5.21, by Microsoft (CP/M version). These programs are designed to be used interactively on a terminal or a hard copy printer. The first program is the input parameter program which accepts the input parameters and formats them into a BASIC

sequential file. The second program is the ECOPATH model itself. This program uses the file created by the input program and allows parameter changes. The intent is to allow modification to the parameters of the ecosystem and show their immediate impact on prior runs. This change-and-run process may be done successively until the desired parameters are realized, with the option of saving them after each trial run.

The input program requests the following information in the order presented. The variable names used in both programs are given in parentheses.

1. (FLNAME\$). The name of the file to be created. This name should follow the file naming conventions of the system used.

NOTE: The program does not check for files already existing with this name and will write over an existing file. Character variable.
2. (N). The number of species groups. Numeric variable with no decimal point.
3. (SPECIE\$(N)). N-species group names. Character variable (first 15 characters used).
4. (NFLAG(N)). Indication of a fixed biomass estimate provided by entering a "1" or a "0" for each species group. A "1" indicates that an estimate of species group biomass will be provided, a "0" allows ECOPATH to estimate it.
5. (B(N)). The biomass estimates for the species indicated by a "1" in response to 4. Numeric with a decimal point as needed.
6. (CFLAG\$(N)). Indicator of catch data to be provided by entering a "1" or a "0" for each species group.
7. (CATCH(N)). The catch data for each species group indicated by a "1" in response to 6.
8. (Z(N)). Annual production/biomass ratios for the N-species groups. Numeric with a decimal point as needed.
9. (EE(N)). Ecotrophic efficiencies for the N-species groups. Ecotrophic efficiency is the fraction of total mortality due to fishing and predation. Numeric with a decimal point as needed.
10. (HABAR(N)). Habitat areas for the N-species groups. Numeric with a decimal point as needed.
11. (FR(N)). Annual food required as the ratio of annual consumption to mean annual biomass for the N-species groups. Numeric with a decimal point as needed.

12. (DC(N,N)). $N \times N$ diet composition parameters. The first row would make up the diet composition for the first species group and so on. NOTE: The sum of the diet composition vector (row) for each species group must be equal to 1 or 0. The diet composition matrix must sum to 1 for all species, except for primary producers which can sum to 0. Numeric with a decimal point.

If a mistake is made during input, simply continue as it is correctable via the main program (except for the value of N and the species group names).

The input parameter program works in the following manner: First the file name is requested. Next, the number of species groups (N) is requested. The response should be a numeric value without a decimal point such as "15." The next requests are for the N-species group names. These may include blanks, numbers, letters, etc., but only the first 15 characters are used as identification within the ECOPATH main program. Notice that a number is assigned to each species group name. This corresponds to the order in which they are entered. It is a good idea to note the number of each group, as all the following input parameters will be requested in the order that the names were entered. We have found it works well to enter top level predators first and proceed successively down the food chain.

The input parameters will be requested in the order outlined earlier. For further information about the input parameters, please refer to the program listing.

Input errors: All input may be changed via the main program except for the value of N and the species group names.

Stopping the input program: Interrupting the program at any point before the message: ****> CREATING FILE ... will prevent the creation of an undesired file.

File creation: The input parameters are stored in variables (in memory). This means that a file is not being created as input is entered. The file is created after verification that the file name entered is really the one desired. If it is discovered that the file name initially entered is incorrect, simply finish entering the input parameters and enter the letter "N" in response to:

ARE YOU SURE YOU WANT TO USE THE FILENAME ...(Y/N)?

Then enter the desired file name, after the message:

****> CREATING FILE ...

the file is created and all of the input information will be placed into it. The format of the file is outlined in the input program listing

along with further usage notes. Please refer to Appendix II for an example of the input program usage.

The main program performs calculations, provides output, and allows input parameters to be changed. After the creation of an input file, one may interactively adjust the parameters and view their impact upon the model. All of the input parameters may be modified except for the number of species groups (N), and the species group names. After each run, it is possible to save the parameters used in that run in a file. For example, one may save the latest parameters under the same file name as the initial input file, hence defining a new set of baseline parameters, or save it under a new name, thus having two files, the original and the modified parameters.

The main program operates in the following manner. First, the name of the file to be used is requested. This file contains the baseline or original input parameter values. Next, the option of the output size may be modified. "S" indicates a screen or 80-column output to be produced. "P" indicates that a printer or hard copy is to be made. It is important to note that if the "P" option is used, the width of the printer output must be specified to the BASIC system before running the program. For MBASIC users, the command is: WIDTH 132.

Modification of the input values (parameters) may be made at this point. Simply reply "Y" to the request "CHANGES?". If changes are to be made, then a menu associating a single digit to the seven sets of parameters is displayed. Upon choosing the desired parameter set to modify, a menu of the species groups and their corresponding number is displayed.

If no changes are desired, the program will display the input parameters and the results. When this is completed, the option to make changes is presented again. If no changes are desired at this point, the option to save the parameters is given.

EXAMPLES

Appendix III shows an actual run of the ECOPATH program. This example is provided as an installation aid. Note that each species group is equated with a number. This number corresponds with the order in which they were entered (see the input program description). The species group name and number are used interchangeably throughout the program.

There are two places where changes to the parameters are offered. The first is shown in Appendix IV. The second is at the end of a run (see the end of Appendix III). The changes made do not alter the file itself (in these two examples, "JEFF"). If it is desired to save the changes, they can either be saved as a new data set or stored in the original data set to replace the previous values (i.e., saving the input parameters under the name of "JEFF" would replace the existing ones).

The use of the input parameter program is shown in Appendix II. The biomass estimate and catch data require a "1" or "0" to indicate that values will be entered. If a mistake is made such as entering a "2," a warning message is displayed along with the prompt. The diet composition is structured such that all N parameters for a particular species group are entered at one time. The first number of "DC(1,2)" indicates the predator, and the second number indicates the prey. Thus the i^{th} row of the DC(N,N) matrix represents the proportion of various prey in the diet of predator i. Note that the sum of a predators diet consumption must be 1.0 or 0.0. (A sum of 0.0 occurs for primary producers.) If a mistake is made such that 0.33 and 0.77 are entered so $0.33 + 0.77 = 1.1$, then a warning message is displayed along with the prompts. At the end of the program there is a prompt to ensure that the parameters entered will be stored in a file without ruining a previously created file. Once the message "CREATING FILE" is displayed, the file is physically created. Because the program doesn't check for existing file names, it is possible to run over an existing file by entering the same name. For example, if there was a file already called "DATA," then it would be replaced by this current set of parameters.

Appendices V and VI show other warning messages which may be displayed. Appendix V shows that after the habitat area input parameters are displayed, the diagonal elements of the AA matrix ($AA*B=C$) are checked to see that they all are greater than 0. If any are not greater than 0, then they are displayed along with the AA matrix. The program then allows changes to be made. When a diagonal element of the AA matrix is less than or equal to 0, this means mortality exceeds production for that species group and either the P/B ratio should be increased or some of the mortality components reduced until the diagonal element becomes positive. Appendix V shows that after the ecotrophic efficiency input parameters are displayed, the diet consumption rows are checked to see that they sum to 1 (as in the input program, see Appendix II). If a predator's diet consumption doesn't sum to 1 or 0, the name of the species group is displayed and changes are allowed. Thus, the sums of the rows in the diet composition matrix are checked in both the input program and the ECOPATH program.

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Appendix I.--The ECOPATH input parameter and main programs.

```

10 REM *****
20 REM *                               E C O P A T H                               *
30 REM *                               INPUT PARAMETER PROGRAM                       *
40 REM *-----*
50 REM * BY JEFFREY J. POLOVINA
60 REM *   MARK D. OW
70 REM *-----*
80 REM * THIS PROGRAM CREATES A SEQUENTIAL FILE OF INPUT PARAMETERS FOR THE *
90 REM * ECOPATH PROGRAM. THE FILE IS CREATED IN THE FOLLOWING FASHION: *
100 REM *
110 REM *   CARD NUMBER   INFORMATION
120 REM *   -----
130 REM *           1      N = THE NUMBER OF SPECIES GROUPS
140 REM *                   IN THIS SET OF DATA.
150 REM *
160 REM *           2      SPECIE$(1):= THE FIRST SPECIES
170 REM *                   GROUP NAME.
180 REM *
190 REM *           3      >NFLAG(1) = 1 IF BIOMASS ESTIMATE
200 REM *                   ENTERED, 0 IF NONE.
210 REM *                   >CFLAGZ(1) = 1 IF CATCH DATA ENTER-
220 REM *                   ED, 0 IF NONE.
230 REM *                   >CATCH(1):= THE CATCH DATA AS ENT-
240 REM *                   ERED OR SET TO 0.
250 REM *                   >B(1):= THE BIOMASS ESTIMATE AS
260 REM *                   ENTERED OR SET TO 0.
270 REM *                   >Z(1):= THE PRODUCTION/BIOMASS
280 REM *                   RATIO.
290 REM *                   >EE(1):= THE ECOTROPHIC EFFICIENCY.
300 REM *                   >HABAR(1):= THE HABITAT AREA.
310 REM *                   >FR(1):= THE FOOD REQUIRED.
320 REM *
330 REM *           4      SPECIE$(2) THE SECOND SPECIES
340 REM *                   GROUP NAME.
350 REM *
360 REM *           5      >NFLAG(2)   ETC.....
370 REM *
380 REM *   ETC.
390 REM *
400 REM *           2N + 2      DC(1,1):= THE FIRST DIET COMPOS-
410 REM *                   ITION FOR SPECIES GROUP 1.
420 REM *
430 REM *           2N + 3      DC(1,2):= THE SECOND DIET COMP-
440 REM *                   OSITION FOR SPECIES GROUP 1.
450 REM *   ETC.
460 REM *
470 REM *-----*
480 REM * USAGE NOTES:
490 REM *   1) THE DIET COMPOSITION MAY BE REFORMATTED FOR SMALL N OR
500 REM *   OTHER BASICS TO REDUCE THE SIZE OF THE INPUT PARAMETER
510 REM *   FILE. (REMEMBER TO ALSO CHANGE THE MAIN PROGRAM IF DONE.)
520 REM *

```

Appendix I.--Continued.

```

530 REM *          2) THE SUM OF EACH DIET COMPOSITION ROW IS CHECKED TO BE *
540 REM *          1 OR 0. THE TOLERANCE TO THE NUMBER 1 MAY BE CHECKED TO *
550 REM *          THE DESIRED DECIMAL PLACE (SEE VARIABLE SUM). *
560 REM * *
570 REM *          3) THE PROGRAM DOES NOT VERIFY THAT THE FILE NAME TO BE *
580 REM *          CREATED DOES NOT EXIST, AND WILL WRITE OVER AN EXISTING *
590 REM *          FILE IF IN EXISTENCE. (THIS PROTECTION IS POSSIBLE BY *
600 REM *          CHECKING THE RETURN CODE OF THE "OPEN" INSTRUCTION.) *
610 REM * *
620 REM *          4) ERRORS ARE CORRECTABLE USING THE PARAMETER CHANGE *
630 REM *          OPTION IN THE MAIN PROGRAM. (MOST ERRORS EXCEPT FOR THE *
640 REM *          VALUE OF N AND THE SPECIES GROUP NAMES). *
650 REM * *
660 REM *          5) FOR FURTHER INFORMATION, PLEASE REFER TO THE MAIN PROGRAM *
670 REM *          AS WELL AS THE ECOPATH USER MANUAL. *
680 REM * *
690 REM *****
700 REM
710 REM
720 DEFINT I-N
730 DEFDBL A-H,M-Z
740 OPTION BASE 1
750 REM DECLARE THE MINIMUM VALUE OF ARRAY SUBSCRIPTS.
760 REM -----
770 REM
780 PRINT:PRINT:PRINT:PRINT
790 PRINT "***** ECOPATH INPUT PARAMETER FILE PROGRAM *****"
800 PRINT " "
810 INPUT "ENTER THE NAME OF THE FILE FOR THESE INPUT PARAMETERS ";FLNAME$
820 PRINT "THE NAME OF THE FILE TO BE CREATED IS ";FLNAME$
830 PRINT ";", IS THIS CORRECT (Y/N) ";
840 INPUT " ";CORRECT$
850 IF (CORRECT$ = "N") GOTO 800
860 IF (CORRECT$ <> "Y") GOTO 800
870 REM
880 PRINT " ";PRINT " "
890 INPUT "PLEASE ENTER THE NUMBER OF SPECIES GROUPS";N
900 IF (N < 1) THEN PRINT " ":PRINT "SORRY, THAT'S TOO SMALL.":GOTO 880
910 PRINT "THE NUMBER OF SPECIES GROUPS IS";N;"", IS THIS CORRECT (Y/N)";
920 INPUT " ";CORRECT$
930 IF (CORRECT$ = "N") GOTO 880
940 IF (CORRECT$ <> "Y") GOTO 880
950 REM
960 REM =====
970 REM          VARIABLE DECLARATIONS
980 REM -----
990 DIM B(N)
1000 DIM CATCH(N),CFLAG$(N)
1010 DIM DC(N,N)
1020 DIM EE(N)
1030 DIM FR(N)

```


Appendix I.--Continued.

```

1040 DIM HABAR(N)
1050 DIM NFLAG(N)
1060 DIM SPECIE$(N),SUM(N)
1070 DIM Z(N)
1080 REM -----
1090 REM
1100 PRINT " ":PRINT " "
1110 FOR I = 1 TO N
1120     PRINT "ENTER THE NAME OF SPECIES GROUP";I;
1130     LINE INPUT " ";SPECIE$(I)
1140 NEXT I
1150 PRINT:PRINT
1160 FOR I = 1 TO N
1170     PRINT "ENTER '1' IF FIXED BIOMASS ESTIMATE, '0' IF NONE FOR "
;SPECIE$(I);
1180     INPUT " ";NFLAG(I)
1182     IF (NFLAG(I) <> 1 AND NFLAG(I) <> 0) THEN PRINT " "
:PRINT "1 OR 0 PLEASE":GOTO 1170
1190 NEXT I
1200 PRINT:PRINT
1210 FOR I = 1 TO N
1220     IF (NFLAG(I) = 0) THEN B(I) = 0#:GOTO 1250
1230     PRINT "ENTER THE KNOWN BIOMASS/HABITAT AREA FOR ";SPECIE$(I);
1240     INPUT " ";B(I)
1250 NEXT I
1260 PRINT:PRINT
1270 FOR I = 1 TO N
1280     PRINT "ENTER '1' IF CATCH DATA AVAILABLE, '0' IF NONE FOR ";SPECIE$(I);
1290     INPUT " ";CFLAG%(I)
1295     IF (CFLAG%(I) <> 0 AND CFLAG%(I) <> 1) THEN PRINT " ":PRINT
"1 OR 0 PLEASE":GOTO 1280
1300 NEXT I
1310 PRINT:PRINT
1320 FOR I = 1 TO N
1330     IF (CFLAG%(I) = 0) THEN CATCH(I) = 0#:GOTO 1360
1340     PRINT "ENTER THE CATCH DATA FOR ";SPECIE$(I);
1350     INPUT " ";CATCH(I)
1360 NEXT I
1370 PRINT:PRINT
1380 FOR I = 1 TO N
1390     PRINT "ENTER THE PRODUCTION/BIOMASS RATIO FOR ";SPECIE$(I);
1400     INPUT " ";Z(I)
1410 NEXT I
1420 PRINT:PRINT
1430 FOR I = 1 TO N
1440     PRINT "ENTER THE ECOTROPHIC EFFICIENCY FOR ";SPECIE$(I);
1450     INPUT " ";EE(I)
1460 NEXT I
1470 PRINT:PRINT
1480 FOR I = 1 TO N
1490     PRINT "ENTER THE HABITAT AREA FOR ";SPECIE$(I);
1500     INPUT " ";HABAR(I)

```

Appendix I.--Continued.

```

1510 NEXT I
1520 PRINT:PRINT
1530 FOR I = 1 TO N
1540     PRINT "ENTER THE FOOD REQUIRED FOR ";SPECIE$(I);
1550     INPUT " ";FR(I)
1560 NEXT I
1570 PRINT:PRINT
1580 FOR I = 1 TO N
1590     PRINT " "
1600     SUM! = 0!
1610     PRINT "ENTER THE";N;" DIET COMPOSITION PARAMETERS FOR ";SPECIE$(I)
1620     FOR J = 1 TO N
1630         PRINT "ENTER DC(";I;",";J;") ";
1640         INPUT " ";DC(I,J)
1650         SUM! = SUM! + DC(I,J)
1660     NEXT J
1670     IF (SUM! = 0) GOTO 1790
1680     SM! = ABS(SUM! - 1#)
1690     IF ((SM!) < .0001) GOTO 1790
1700 REM
1710 REM MODIFY THE ABOVE INEQUALITY TO VARY THE APPROXIMATION TO 1 BY THE SUM!.
1720 REM -----
1730 REM
1740     PRINT " ":PRINT " "
1750     PRINT "*** WARNING: THE DIET COMPOSITION FOR ";SPECIE$(I);
1760     PRINT " DOES NOT SUM TO 1 OR 0, PLEASE REENTER."
1770     PRINT " "
1780     GOTO 1590
1790     PRINT
1800 NEXT I
1810 PRINT " ":PRINT " "
1820 PRINT "ARE YOU SURE YOU WANT TO USE THE FILE NAME ";FLNAME$; " (Y/N)";
1830 INPUT " ";CORRECT$
1840 IF (CORRECT$ = "Y") GOTO 1890
1850 IF (CORRECT$ <> "N") GOTO 1810
1860 PRINT " "
1870 INPUT "ENTER THE DESIRED FILE NAME ";FLNAME$
1880 GOTO 1810
1890 PRINT " "
1900 PRINT " ****> CREATING FILE ";FLNAME$
1910 OPEN "O",#1,FLNAME$
1920 REM
1930 REM ENTER THE RETURN CODE CHECK HERE PER FILE PROTECTION CAPABILITY
1940 REM -----
1950 REM
1960 PRINT#1,N
1970 FOR I = 1 TO N
1980     PRINT#1,SPECIE$(I)
1990     PRINT#1,NFLAG(I);CFLAGZ(I);CATCH(I);B(I);Z(I);EE(I);HABAR(I);FR(I)
2000 NEXT I
2010 FOR I = 1 TO N
2020     FOR J = 1 TO N

```

Appendix I.--Continued.

```
2030      PRINT#1,DC(I,J)
2040      NEXT J
2050 NEXT I
2060 CLOSE
2070 PRINT "FILE ";FLNAME$;" HAS BEEN CREATED."
2080 PRINT:PRINT:PRINT "***** END OF INPUT PROGRAM *****"
2090 END
```

Appendix I.--Continued.

```

10 REM *****
20 REM *                                     E C O P A T H                                     *
30 REM *-----*
40 REM * BY JEFFREY J. POLOVINA *
50 REM * MARK D. OW *
60 REM *
70 REM *=====*
80 REM * THIS PROGRAM IS WRITTEN IN MICROSOFT (TM) BASIC - 80 REV. 5.21 *
90 REM * CP/M VERSION. THE PROGRAMMING CONSTRUCTS WHICH WILL DIFFER FROM *
100 REM * OTHER BASICS ARE THE "WHILE/WEND" CONSTRUCT AND THE OUTPUT FORMATS. *
110 REM * THE WHILE CONSTRUCTS MAY BE IMPLEMENTED VIA A "FOR/NEXT" CONSTRUCT *
120 REM * WITH AN "IF" CONTROL STATEMENT. *
122 REM *
124 REM * NOTE:THE COMMENTS INCLUDED THROUGHOUT THIS PROGRAM MAY CAUSE MEMORY *
126 REM * ALLOCATION PROBLEMS ON SMALLER SYSTEMS. *
130 REM *=====*
140 REM * DICTONARY OF VARIABLES *
150 REM * ===== *
160 REM *
170 REM * AA(N,N) COEFFICIENT MATRIX PER  $AA*B = C$  *
180 REM *
190 REM * AASV(N,N) SAME AS ABOVE, USED IN ACTUAL COMPUTAIONS *
200 REM *
210 REM * ANPROD(N) ANNUAL PRODUCTION OUTPUT VECTOR *
220 REM *
230 REM * ARRAYA(N*N) COLUMN-WISE VECTOR OF THE AA(N,N) MATRIX *
240 REM * WHERE ARRAYA(3) = AA(1,3) *
250 REM *
260 REM * B(N) INITALLY A VECTOR OF THE MEAN ANNUAL SPECIES *
270 REM * GROUP BIOMASS, AFTER COMPUTATION OF  $A*B = C$ , *
280 REM * THE NONTRIVIAL SOLUTION VECTOR *
290 REM *
300 REM * BEATEN(N,N) CONSUMPTION OUTPUT MATRIX *
310 REM *
320 REM * BSTPHA(N) BIOMASS PER UNIT OF HABITAT AREA OUPUT VECTOR *
330 REM *
340 REM * C(N) VECTOR OF FISHERIES CATCH PER  $A*B = C$  *
350 REM *
360 REM * CATCH(N) CATCH INPUT VECTOR *
370 REM *
380 REM * CFLAGZ(N) INDICATES THE PRESENCE OF NON-ZERO CATCH INPUT *
390 REM * 1 = PRESENT, 0 = NOT PRESENT *
400 REM *
410 REM * D(N) VECTOR OF  $(1 - EE(I)) * Z(I)$  *
420 REM *
430 REM * DC(N,N) DIET COMPOSITION INPUT MATRIX *
440 REM *
450 REM * DISPLAY$ "S" = SCREEN OUTPUT, "P" = PRINTER OUTPUT *
460 REM * LIMITS OF 80 AND 132 COLUMNS RESPECTIVELY *
470 REM * USAGE NOTE: IF A PRINTER IS SLAVED, THEN THE *
480 REM * PRINTER MODE MAY BE USED IF THE SCREEN OUTPUT *
490 REM * WIDTH IS DEFINED AS 132 (I.E. ENTER 'WIDTH 132')*

```


Appendix I.--Continued.

500	REM	*		*	
510	REM	*	ECFF(N)	ECOLOGICAL EFFICIENCY (PRODUCTION/CONSUMPTION)	*
520	REM	*		OUTPUT VECTOR	*
530	REM	*			*
540	REM	*	EE(N)	ECOTROPHIC EFFICIENCY INPUT VECTOR	*
550	REM	*			*
560	REM	*	FCATCH(N)	FISHERY CATCH OUTPUT VECTOR	*
570	REM	*			*
580	REM	*	FLNAME\$	SEQUENTIAL FILE OF INPUT PARAMETERS CREATED BY	*
590	REM	*		THE ECOPATH INPUT PROGRAM OR THIS PROGRAM	*
600	REM	*			*
610	REM	*	FR(N)	FOOD REQUIRED INPUT VECTOR	*
620	REM	*			*
630	REM	*	HABAR(N)	HABITAT AREA INPUT VECTOR	*
640	REM	*			*
650	REM	*	INCREMENT	THE NUMBER OF OUTPUT ITEMS THAT WILL FIT ON ONE	*
660	REM	*		SCREEN PAGE (IF DISPLAY\$ = "S") OR PRINTER PAGE	*
670	REM	*			*
680	REM	*	NEGFLAG(N)	INDICATES THE PRESENCE OF AA MATRIX DIAGONAL	*
690	REM	*		ELEMENTS WHICH ARE LESS THAN OR EQUAL TO 0	*
700	REM	*		1 = DIAGONAL <= 0, 0 = DIAGONAL > 0	*
710	REM	*			*
720	REM	*	NFLAG(N)	INDICATES THE PRESENCE OF FIXED INPUT BIOMASS	*
730	REM	*		ESTIMATES. 1 = PRESENT ,0 = NOT PRESENT AND	*
740	REM	*		THE CORRESPONDING B INPUT ELEMENT SET TO 0.0	*
750	REM	*			*
760	REM	*	OLDB(N)	STORAGE VECTOR OF B VALUES BEFORE SOLUTION	*
770	REM	*			*
780	REM	*	OLDCATCH(N)	STORAGE VECTOR OF CATCH VALUES BEFORE USE IN	*
790	REM	*		COMPUTATION	*
800	REM	*			*
810	REM	*	SPECIE\$(N)	SPECIES GROUP NAMES (ONLY FIRST 15 CHARACTERS	*
820	REM	*		USED PER OUTPUT)	*
830	REM	*			*
840	REM	*	SUM!(N)	THE SUM OF THE ITH ROW OF DC(I,J). IF NOT EQUAL	*
850	REM	*		TO 1 OR 0, THEN ERROR IS FLAGGED	*
860	REM	*	TOTAL(N)	THE SUM OF THE JTH COLUMN OF BEATEN(I,J)	*
870	REM	*			*
880	REM	*	Z(N)	PRODUCTION/BIOMASS RATIO WHERE Z = M + F INPUT	*
890	REM	*		VECTOR	*
900	REM	*			*
910	REM	*	-----	-----	*
920	REM	*	DEFINT	DEFINES ALL VARIABLES STARTING WITH THE LETTERS	*
930	REM	*		I THRU N TO BE INTEGERS	*
940	REM	*	DEFDBL	DEFINES ALL VARIABLES STARTING WITH THE LETTERS	*
950	REM	*		A THRU H AND M THRU Z TO BE DOUBLE PRECISION	*
960	REM	*			*
970	REM	*	NOTE: VARIABLES ENDING WITH THE FOLLOWING CHARACTERS DO NOT FOLLOW		*
980	REM	*	THE ABOVE DEFINITIONS:		*
990	REM	*			*
1000	REM	*	%	INTEGER NUMBERS OR VARIABLES	*
1010	REM	*	!	SINGLE PRECISION NUMBERS OR VARIABLES	*

Appendix I.--Continued.

```

1020 REM*                                #      DOUBLE PRECISION NUMBERS OR VARIABLES      *
1030 REM*                                $      STRING VARIABLES                          *
1040 REM*****
1050 REM
1060 REM
1070 DEFINT I-N
1080 DEFDBL A-H,M-Z
1090 OPTION BASE 1
1100 REM DECLARE THE MINIMUM VALUE OF ARRAY SUBSCRIPTS.
1110 REM -----
1120 PRINT " ":PRINT "          ***** E C O P A T H *****"
1130 PRINT " ":PRINT " "
1140 INPUT "PLEASE ENTER THE NAME OF THE FILE TO BE USED ";FLNAME$
1150 PRINT "THE FILE TO BE USED IS ";FLNAME$;", IS THIS CORRECT (Y/N) ";
1160 INPUT " ";CORRECT$
1170 IF (CORRECT$ = "N") GOTO 1130
1180 IF (CORRECT$ <> "Y") GOTO 1130
1190 OPEN "I",#1,FLNAME$
1200 INPUT #1,N
1210 REM INPUT THE NUMBER OF SPECIES GROUPS
1220 REM -----
1230 DIM AA(N,N),AASV(N,N),ANPROD(N),ARRAYA(N*N)
1240 DIM B(N),BEATEN(N,N),BSTPHA(N)
1250 DIM C(N),CATCH(N),CFLAG%(N)
1260 DIM D(N),DC(N,N)
1270 DIM ECF(N),EE(N)
1280 DIM FCATCH(N),FR(N)
1290 DIM HABAR(N),NEGFLAG(N),NFLAG(N),OLDB(N),OLDCATCH(N)
1300 DIM SPECIE$(N),SUM!(N)
1310 DIM TOTAL(N),Z(N)
1320 PRINT " "
1330 INPUT "ARE YOU USING A SCREEN OR A PRINTER (S/P) ";DISPLAY$
1340 IF (DISPLAY$ <> "S" AND DISPLAY$ <> "P") GOTO 1320
1350 PRINT " "
1360 PRINT " "
1370 REM =====
1380 REM                      INPUT SECTION
1390 REM -----
1400 FOR I = 1 TO N
1410     LINE INPUT#1,SPECIE$(I)
1420     INPUT#1,NFLAG(I),CFLAG%(I),CATCH(I),B(I),Z(I),EE(I),HABAR(I),FR(I)
1430 NEXT I
1440 FOR I = 1 TO N
1450     FOR J = 1 TO N
1460         INPUT#1,DC(I,J)
1470     NEXT J
1480 NEXT I
1490 REM =====
1500 REM
1510 INPUT "WOULD YOU LIKE TO MAKE ANY CHANGES TO THE INPUT VALUES NOW (Y/N)";NOW$
1520 IF (NOW$ = "Y") GOTO 7110
1530 IF (NOW$ <> "N") GOTO 1510

```

Appendix I.--Continued.

```

1540 REM =====
1550 REM                               INPUT DISPLAY AND PROCESSING
1560 REM -----
1570 REM
1580 PRINT " ":PRINT " ":PRINT " "
1590 PRINT "     SPECIES GROUPS"
1600 PRINT " "
1610 FOR I = 1 TO N
1620     PRINT USING "          ##";I;
1630     PRINT " = ";SPECIE$(I)
1640 NEXT I
1650 PRINT " "
1660 PRINT " "
1670 PRINT " "
1680 PRINT " "
1690 PRINT "          KNOWN BIOMASS/(WEIGHT/UNIT AREA OVER HABITAT AREA)    (B)"
1700 PRINT " "
1710 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8
1720 K = 1
1730 J = 1
1740 WHILE (J <= N)
1750     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
1760     FOR I = 1 TO INCREMENT
1770         PRINT USING "          ##";J;
1780         J = J + 1
1790     NEXT I
1800     PRINT " "
1810     PRINT " "
1820     FOR I = 1 TO INCREMENT
1830         PRINT USING "#####.###";B(K);
1840         K = K + 1
1850     NEXT I
1860     PRINT " "
1870     PRINT " "
1880 WEND
1890 PRINT " "
1900 PRINT " "
1910 PRINT " "
1920 PRINT " "
1930 PRINT " "
1940 PRINT " "
1950 PRINT " "
1960 PRINT " "
1970 PRINT "          TOTAL CATCH/(WEIGHT/UNIT AREA OVER HABITAT AREA)
      (CATCH)"
1980 PRINT " "
1990 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8
2000 K = 1
2010 J = 1
2020 WHILE (J <= N)
2030     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
2040     FOR I = 1 TO INCREMENT

```


Appendix I.--Continued.

```

2050      PRINT USING "          ##";J;
2060      J = J + 1
2070      NEXT I
2080      PRINT " "
2090      PRINT " "
2100      FOR I = 1 TO INCREMENT
2110          PRINT USING "#####.###";CATCH(K);
2120          K = K + 1
2130      NEXT I
2140      PRINT " "
2150      PRINT " "
2160      WEND
2170      PRINT " "
2180      PRINT " "
2190      PRINT " "
2200      PRINT " "
2210      PRINT "          ECOTROPHIC EFFICIENCY (FRACTION OF PRODUCTION
CONSUMED BY PREDATORS) (EE)"
2220      IF (DISPLAY$ = "S") THEN INCREMENT = 8   ELSE INCREMENT = 14
2230      K = 1
2240      J = 1
2250      WHILE (J <= N)
2260          IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
2270          FOR I = 1 TO INCREMENT
2280              PRINT USING "          ##";J;
2290              J = J + 1
2300          NEXT I
2310          PRINT " "
2320          PRINT " "
2330          FOR I = 1 TO INCREMENT
2340              PRINT USING "      ##.###";EE(K);
2350              K = K + 1
2360          NEXT I
2370          PRINT " "
2380          PRINT " "
2390      WEND
2400      FOR I = 1 TO N
2410          SUM!(I) = 0!
2420          FOR J = 1 TO N
2430              SUM!(I) = CSNG(DC(I,J)) + SUM!(I)
2440          NEXT J
2450      NEXT I
2460      REM
2470      REM CHECK THAT THE DIET COMPOSITION FOR A SPECIES GROUP SUMS TO 1 OR 0 BY
2480      REM A TOLERANCE OF SM! . IF THE SUM! IS OFF, THEN ALLOW THE USER TO
2490      REM ENTER CHANGES.
2500      REM -----
2510      REM
2520      FOR I = 1 TO N
2530          IF (SUM!(I) = 0!) GOTO 2630
2540          SM! = ABS(SUM!(I) - 1#)
2550          IF (SM! < .0001) GOTO 2630

```

Appendix I.--Continued.

```

2560     PRINT " ";PRINT " "
2570     PRINT "*** WARNING: THE DIET COMPOSITION FOR THE FOLLOW SPECIES"
2580     PRINT "                DOES NOT SUM TO 1 OR 0, PLEASE VERIFY DC INPUT"
2590     PRINT " "
2600     PRINT "                ";SPECIE$(I)
2610     PRINT " "
2620     BADD$ = "Y"
2630 NEXT I
2640 IF (BADD$ = "Y") GOTO 6980
2650 REM
2660 IF (DISPLAY$ = "S") THEN INCREMENT = 6 ELSE INCREMENT = 12
2670 PRINT " "
2680 PRINT " "
2690 PRINT " "
2700 PRINT " "
2710 PRINT " "
2720 PRINT "                DIET COMPOSITION BY SPECIES GROUPS (DC)"
2730 PRINT "                (ROWS REPRESENT PREDATORS AND COLUMNS ARE PREY)"
2740 PRINT " "
2750 K = 1
2760 J = 1
2770 WHILE (J <= N)
2780     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
2790     PRINT "                ";
2800     FOR I = 1 TO INCREMENT
2810         PRINT USING "                ##";J;
2820         J = J + 1
2830     NEXT I
2840     IF ((J-1) = N) THEN PRINT "                SUM" ELSE PRINT " "
2850     FOR L = 1 TO N
2860         K = (J - INCREMENT)
2870         PRINT USING "                *";SPECIE$(L);
2880         PRINT USING "                ##";L;
2890         FOR I = 1 TO INCREMENT
2900             PRINT USING "                ##.##";DC(L,K);
2910             K = K + 1
2920         NEXT I
2930         IF ((K-1) = N) THEN PRINT USING "                ##.##";SUM(L) ELSE PRINT " "
2940     NEXT L
2950     PRINT " "
2960     PRINT " "
2970 WEND
2980 PRINT " "
2990 PRINT " "
3000 PRINT " "
3010 PRINT " "
3020 PRINT " "
3030 PRINT " "
3040 PRINT " "
3050 PRINT "                PRODUCTION/BIOMASS RATIO (Z = M + F)"
3060 PRINT " "
3070 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8

```

Appendix I.--Continued.

```

3080 K = 1
3090 J = 1
3100 WHILE (J <= N)
3110     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
3120     FOR I = 1 TO INCREMENT
3130         PRINT USING "                ##";J;
3140         J = J + 1
3150     NEXT I
3160     PRINT " "
3170     PRINT " "
3180     FOR I = 1 TO INCREMENT
3190         PRINT USING "#####.###";Z(K);
3200         K = K + 1
3210     NEXT I
3220     PRINT " "
3230     PRINT " "
3240 WEND
3250 PRINT " "
3260 PRINT " "
3270 FOR I = 1 TO N
3280     D(I) = (1# - EE(I))*Z(I)
3290 NEXT I
3300 PRINT " "
3310 PRINT " "
3320 PRINT "          ANNUAL FOOD REQUIRED AS A FRACTION OF THE
    MEAN ANNUAL BIOMASS (FR)"
3330 PRINT " "
3340 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8
3350 PRINT " "
3360 K = 1
3370 J = 1
3380 WHILE (J <= N)
3390     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
3400     FOR I = 1 TO INCREMENT
3410         PRINT USING "                ##";J;
3420         J = J + 1
3430     NEXT I
3440     PRINT " "
3450     PRINT " "
3460     FOR I = 1 TO INCREMENT
3470         PRINT USING "#####.###";FR(K);
3480         K = K + 1
3490     NEXT I
3500     PRINT " "
3510     PRINT " "
3520 WEND
3530 PRINT " "
3540 PRINT " "
3550 PRINT " "
3560 PRINT " "
3570 PRINT " "
3580 PRINT "          HABITAT AREA  (HABAR)"

```

Appendix I.--Continued.

```

3590 PRINT " "
3600 PRINT " "
3610 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8
3620 K = 1
3630 J = 1
3640 WHILE (J <= N)
3650     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
3660     FOR I = 1 TO INCREMENT
3670         PRINT USING "          ##";J;
3680         J = J + 1
3690     NEXT I
3700     PRINT " "
3710     PRINT " "
3720     FOR I = 1 TO INCREMENT
3730         PRINT USING "#####.###";HABAR(K);
3740         K = K + 1
3750     NEXT I
3760     PRINT " "
3770     PRINT " "
3780 WEND
3790 PRINT " "
3800 PRINT " "
3810 PRINT " "
3820 PRINT " "
3830 PRINT " "
3840 REM
3850 REM STORE THE CURRENT VALUES OF B(N) PER LATER REFERENCE IN OLDB(N)
3860 REM
3870 FOR I = 1 TO N
3880     OLDB(I) = B(I)
3890     IF (NFLAG(I) = 1) THEN B(I) = B(I)*HABAR(I)
3900 NEXT I
3910 REM
3920 REM INITIALIZE THE MATRICES FOR SOLUTION OF THE EQUALIBRIUM MATRIX PER
3930 REM AA*B = C.
3940 REM -----
3950 REM
3960 FOR J = 1 TO N
3970     C(J) = 0#
3980     IF (NFLAG(J) = 1) GOTO 4020
3990     FOR I = 1 TO N
4000         IF (NFLAG(I) = 1) THEN C(J) = B(I)*FR(I)*DC(I,J) + C(J)
4010     NEXT I
4020 NEXT J
4030 REM
4040 REM FOR THE SPECIES GROUPS WHICH CONTAIN BIOMASS ESTIMATES (FROM INPUT)
4050 REM SET THE DIAGONAL OF THE AA MATRIX TO 1.
4060 REM -----
4070 REM
4080 FOR I = 1 TO N
4090     IF (NFLAG(I) = 0) GOTO 4150
4100     C(I) = B(I)

```

Appendix I.--Continued.

```

4110   FOR J = 1 TO N
4120     AA(I,J) = 0#
4130     IF (I = J) THEN AA(I,J) = 1#
4140   NEXT J
4150 NEXT I
4160 FOR I = 1 TO N
4170   OLDCATCH(I) = CATCH(I)
4180   FCATCH(I) = CATCH(I)
4190   CATCH(I) = CATCH(I)*HABAR(I)
4200   IF (CFLAG%(I) = 1) THEN C(I) = C(I) + CATCH(I)
4210 NEXT I
4220 FOR I = 1 TO N
4230   FOR J = 1 TO N
4240     IF (NFLAG(I) = 1 OR NFLAG(J) = 1) GOTO 4260
4250     IF (J = I) THEN AA(I,J) = Z(I)-D(I)-FR(J)*DC(J,I)
        ELSE AA(I,J) = -FR(J)*DC(J,I)
4260   NEXT J
4270 NEXT I
4280 FOR I = 1 TO N
4290   FOR J = 1 TO N
4300     AASV(I,J) = AA(I,J)
4310   NEXT J
4320 NEXT I
4330 REM *****
4340 NEGATIVE = 0
4350 FOR I = 1 TO N
4360   NEGFLAG(I) = 0
4370 NEXT I
4380 REM
4390 REM IF A DIAGONAL ELEMENT OF THE AA MATRIX IS LESS THAN OR EQUAL TO 0,
4400 REM OUTPUT THE AA MATRIX AND ALLOW THE USER TO MAKE CHANGES.
4410 REM -----
4420 REM
4430 FOR I = 1 TO N
4440   IF (AASV(I,I) <= 0#) THEN NEGFLAG(I) = 1:NEGATIVE = 1
4450 NEXT I
4460 IF (NEGATIVE = 0) GOTO 5210
4470 PRINT " "
4480 PRINT " "
4490 PRINT " "
4500 PRINT " "
4510 PRINT " "
4520 PRINT " "
4530 PRINT " "
4540 PRINT " "
4550 PRINT "      ** WARNING :THE DIAGONAL ENTRIES IN THE AA MATRIX ARE NOT"
4560 PRINT "      POSITIVE FOR THE FOLLOWING SPECIES GROUPS:"
4570 PRINT " "
4580 PRINT " "
4590 PRINT "      SPECIES GROUP      LOCATION      VALUE"
4600 PRINT "      _____      _____      _____"
4610 FOR I = 1 TO N

```


Appendix I.--Continued.

```

4620     IF (NEGFLAG(I) <> 1) GOTO 4710
4630     PRINT " ";
4640     PRINT USING "•",SPECIE$(I);
4650     PRINT "  AA(";
4660     PRINT USING "##";I;
4670     PRINT ",";
4680     PRINT USING "##";I;
4690     PRINT ")";
4700     PRINT USING "    ###.###";AASV(I,I)
4710 NEXT I
4720 PRINT " "
4730 PRINT " "
4740 PRINT " "
4750 PRINT " "
4760 PRINT " "
4770 PRINT "      ***> NOTE: THE ABOVE INDICATES THAT PREDATION PLUS
FISHING (AS APPLICABLE)"
4780 PRINT "      IS EXCEEDING PRODUCTION.  THE EQUALIBRI
UM BIOMASS ESTIMATES"
4790 PRINT "      AS A RESULT, ARE NEGATIVE.  THEREFORE,
THE"
4800 PRINT "      EQUALIBRIUM BIOMASS OUTPUT HAS BEEN SUP
PRESSED."
4810 PRINT " "
4820 PRINT " "
4830 PRINT "      PLEASE CHECK THE INPUT VALUES OF: DIET
COMPOSITION,"
4840 PRINT "      PRODUCTION/BIOMASS, AND FOOD REQUIREME
NTS FOR THE"
4850 PRINT "      SPECIES GROUPS LISTED ABOVE AND RERUN
THE PROGRAM."
4860 PRINT " "
4870 PRINT " "
4880 PRINT " "
4890 PRINT " "
4900 PRINT " "
4910 PRINT " "
4920 PRINT "      THE AA MATRIX"
4930 PRINT " "
4940 PRINT " "
4950 PRINT " "
4960 IF (DISPLAY$ = "S") THEN INCREMENT = 4 ELSE INCREMENT = 8
4970 K = 1
4980 J = 1
4990 WHILE (J <= N)
5000     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
5010     PRINT " ";
5020     FOR I = 1 TO INCREMENT
5030         PRINT USING "    ##";J;
5040         J = J + 1
5050     NEXT I
5060     PRINT " "

```

Appendix I.--Continued.

```

5070 PRINT " "
5080 FOR L = 1 TO N
5090     K = (J - INCREMENT)
5100     PRINT USING "●" "●";SPECIE$(L);
5110     PRINT USING "##";L;
5120     FOR I = 1 TO INCREMENT
5130         PRINT USING "#####.###";AASV(L,K);
5140         K = K + 1
5150     NEXT I
5160     PRINT " "
5170 NEXT L
5180 PRINT " "
5190 WEND
5200 GOTO 6980
5210 PRINT " "
5220 PRINT " "
5230 PRINT " "
5240 PRINT " "
5250 PRINT " "
5260 FOR I = 1 TO N
5270     B(I) = C(I)
5280 NEXT I
5290 REM ++++++
5300 REM SUBROUTINE CALL TO OBTAIN A SOLUTION TO LINEAR EQUATION AA*B = C
5310 REM FOR EQUALIBRIUM, C VECTOR REPLACES B VECTOR, CALCULATE THE BIOMASSES
5320 REM USING THE VALUES IN C WITH THE SOLUTION REPLACING THE VALUES IN B.
5330 REM -----
5340 GOSUB 8610
5350 REM ++++++
5360 REM
5370 PRINT " "
5380 PRINT " "
5390 PRINT " "
5400 PRINT " "
5410 PRINT " "
5420 PRINT " "
5430 PRINT " "
5440 PRINT " "
5450 PRINT "          INITIAL EQUALIBRIUM"
5460 PRINT " "
5470 PRINT " "
5480 FOR I = 1 TO N
5490     BSTPHA(I) = B(I)/HABAR(I)
5500     ANPROD(I) = (Z(I)*B(I))/HABAR(I)
5510     IF (ABS(FR(I)) >= .001# AND ABS(B(I)) >= .001#)
5520         THEN ECFF(I) = ANPROD(I) / (FR(I)*BSTPHA(I))
5520 NEXT I
5530 PRINT " "
5540 PRINT " "
5550 PRINT "          BIOMASS RECALCULATED PER HABITAT AREA FOR OUTPUT"
5560 PRINT " "
5570 PRINT " "

```


Appendix I.--Continued.

```

5580 PRINT " "
5590 PRINT "          BIOMASS      ANNUAL      FISHERY      HABITAT
      ECOLOGICAL"
5600 PRINT "          PER UNIT      PRODUCTION      CATCH PER      AREA
      EFFICIENCY"
5610 PRINT "          OF HABITAT      PER UNIT      UNIT OF
      (PRODUCTION/"
5620 PRINT "          AREA      HABITAT      HABITAT
      CONSUMPTION)"
5630 PRINT "          AREA      AREA"
5640 PRINT " "
5650 FOR I = 1 TO N
5660   PRINT USING "●"          "●";SPECIE$(I);
5670   PRINT USING " ## ";I;
5680   PRINT USING "#####";BSTPHA(I);
5690   PRINT USING " #####";ANPROD(I);
5700   PRINT USING " #####";FCATCH(I);
5710   PRINT USING " #####";HABAR(I);
5720   PRINT USING " #####.####";ECFF(I)
5730 NEXT I
5740 PRINT " "
5750 PRINT " "
5760 PRINT " "
5770 PRINT " "
5780 PRINT " "
5790 PRINT " "
5800 FOR I = 1 TO N
5810   TOTAL(I) = 0#
5820   FOR J = 1 TO N
5830     BEATEN(I,J) = (B(I)/HABAR(I))*FR(I)*DC(I,J)
5840     TOTAL(I) = TOTAL(I) + BEATEN(I,J)
5850   NEXT J
5860 NEXT I
5870 IF (DISPLAY$ = "S") THEN INCREMENT = 3 ELSE INCREMENT = 6
5880 PRINT "          CONSUMPTION VECTOR (BIOMASS/HABITAT AREA)"
5890 PRINT "          (COLUMNS REPRESENT PERDATOR, ROWS REPRESENT PREY)"
5900 PRINT " "
5910 K = 1
5920 J = 1
5930 WHILE (J <= N)
5940   IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
5950   PRINT "          ";
5960   FOR I = 1 TO INCREMENT
5970     PRINT USING "          ##";J;
5980     J = J + 1
5990   NEXT I
6000   PRINT " "
6010   PRINT " "
6020   FOR L = 1 TO N
6030     K = (J - INCREMENT)
6040     PRINT USING "●"          "●";SPECIE$(L);
6050     PRINT USING " ##";L;

```

Appendix I.--Continued.

```

6060      FOR I = 1 TO INCREMENT
6070          PRINT USING " #####.##";BEATEN(K,L);
6080          K = K + 1
6090      NEXT I
6100      PRINT " "
6110  NEXT L
6120      PRINT " "
6130      PRINT "TOTAL          ";
6140      K = (J - INCREMENT)
6150      FOR I = 1 TO INCREMENT
6160          PRINT USING " #####.##";TOTAL(K);
6170          K = K + 1
6180      NEXT I
6190      PRINT " "
6200      PRINT " "
6210 WEND
6220 PRINT " "
6230 PRINT " "
6240 PRINT " "
6250 PRINT " "
6260 PRINT " "
6270 PRINT " "
6280 PRINT " "
6290 PRINT " "
6300 PRINT " "
6310 PRINT "          C VECTOR"
6320 PRINT " "
6330 PRINT " "
6340 IF (DISPLAY$ = "S") THEN INCREMENT = 5 ELSE INCREMENT = 8
6350 K = 1
6360 J = 1
6370 WHILE (J <= N)
6380     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
6390     FOR I = 1 TO INCREMENT
6400         PRINT USING "          ##";J;
6410         J = J + 1
6420     NEXT I
6430     PRINT " "
6440     PRINT " "
6450     FOR I = 1 TO INCREMENT
6460         PRINT USING "#####.###";C(K);
6470         K = K + 1
6480     NEXT I
6490     PRINT " "
6500     PRINT " "
6510 WEND
6520 PRINT " "
6530 PRINT " "
6540 PRINT " "
6550 PRINT " "
6560 PRINT " "
6570 PRINT " "

```

Appendix I.--Continued.

```

6580 PRINT " "
6590 PRINT "          AA MATRIX"
6600 PRINT " "
6610 PRINT " "
6620 IF (DISPLAY$ = "S") THEN INCREMENT = 4 ELSE INCREMENT = 8
6630 K = 1
6640 J = 1
6650 WHILE (J <= N)
6660     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
6670     PRINT "          ";
6680     FOR I = 1 TO INCREMENT
6690         PRINT USING "          ##";J;
6700         J = J + 1
6710     NEXT I
6720     PRINT " "
6730     PRINT " "
6740     FOR L = 1 TO N
6750         K = (J - INCREMENT)
6760         PRINT USING "          •";SPECIE$(L);
6770         PRINT USING "          ##";L;
6780         FOR I = 1 TO INCREMENT
6790             PRINT USING "          #####.###";AASV(L,K);
6800             K = K + 1
6810         NEXT I
6820         PRINT " "
6830     NEXT L
6840     PRINT " "
6850 WEND
6860 REM
6870 REM =====
6880 REM                      PARAMETER CHANGE SECTION
6890 REM -----
6900 REM
6910 REM ALLOW THE USER TO MODIFY THE CURRENT PARAMETERS AND MAKE ANOTHER RUN,
6920 REM AND/OR ALLOW THE USER TO SAVE THE CURRENT PARAMETERS IN A SEQUENTIAL
6930 REM FILE.  NOTE: PROGRAM DOES NOT VERIFY IF THE NAME OF THE FILE TO
6940 REM          BE CREATED ALREADY EXIST.  IF IT DOES, THEN THE CONTENTS
6950 REM          WILL BE WRITTEN OVER.
6960 REM -----
6970 REM
6980 PRINT " "
6990 PRINT " "
7000 INPUT "WOULD YOU LIKE TO CHANGE ANY INPUT PARAMETERS (Y/N)";CHANGE$
7010 IF (CHANGE$ = "N") GOTO 8310
7020 IF (CHANGE$ <> "Y") GOTO 7000
7030 REM
7040 REM RESTORE THE CURRENT B AND CATCH PARAMETERS
7050 REM -----
7060 REM
7070 FOR I = 1 TO N
7080     B(I) = OLDB(I)
7090     CATCH(I) = OLDCATCH(I)

```

Appendix I.--Continued.

```

7100 NEXT I
7110 PRINT " ":PRINT " ":PRINT " ":PRINT " "
7120 PRINT "      1 = KNOWN BIOMASS/HABITAT AREA (B)"
7130 PRINT "      2 = TOTAL CATCH/HABITAT AREA (CATCH)"
7140 PRINT "      3 = ECOTROPHIC EFFICIENCY (EE)"
7150 PRINT "      4 = DIET COMPOSITION (DC)"
7160 PRINT "      5 = PRODUCTION/BIOMASS RATIO (Z = M + F)"
7170 PRINT "      6 = FOOD REQUIRED (FRACTION OF MEAN ANNUAL BIOMASS) (FR)"
7180 PRINT "      7 = HABITAT AREA (HABAR)"
7190 PRINT "      8 = NO MORE CHANGES TO BE MADE (MAKE ANOTHER PASS)"
7200 PRINT " "
7210 INPUT "ENTER THE NUMBER OF YOUR CHOICE (1-8)";CHOICE%
7220 IF (CHOICE% < 1 OR CHOICE% > 8) GOTO 7210
7230 PRINT " ":PRINT " ":PRINT " "
7240 IF (CHOICE% = 8) THEN PRINT " ***** NEW RUN
      *****" : GOTO 1540
7250 INCREMENT = 4
7260 K = 1
7270 J = 1
7280 WHILE (J <= N)
7290     IF ((N - K + 1) < INCREMENT) THEN INCREMENT = (N - K + 1)
7300     FOR I = 1 TO INCREMENT
7310         PRINT USING "##" "J;
7320         J = J + 1
7330     NEXT I
7340     PRINT " "
7350     PRINT " "
7360     FOR I = 1 TO INCREMENT
7370         PRINT USING "●" "● _ ";SPECIE$(K);
7380         K = K + 1
7390     NEXT I
7400     PRINT " "
7410     PRINT " "
7420 WEND
7430 PRINT " ":PRINT " "
7440 IF (CHOICE% <> 1) GOTO 7550
7450     PRINT "ENTER THE NUMBER OF THE BIOMASS/HABITAT PARAMETER TO"
7460     PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
7470     INPUT " ";CHANGE%
7480     IF (CHANGE% = 0) GOTO 7110
7490     IF (CHANGE% < 1 OR CHANGE% > N) GOTO 7450
7500     PRINT "THE VALUE IS CURRENTLY ";B(CHANGE%)
7510     INPUT "ENTER THE NEW VALUE ";B(CHANGE%)
7520     IF (B(CHANGE%) = 0# OR B(CHANGE%) = 0! OR B(CHANGE%) = 0)
       THEN NFLAG(CHANGE%) = 0 ELSE NFLAG(CHANGE%) = 1
7530     PRINT " "
7540     GOTO 7450
7550 IF (CHOICE% <> 2) GOTO 7660
7560     PRINT "ENTER THE NUMBER OF THE CATCH/HABITAT PARAMETER TO"
7570     PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
7580     INPUT " ";CHANGE%
7590     IF (CHANGE% = 0) GOTO 7110

```


Appendix I.--Continued.

```

7600     IF (CHANGE% < 1 OR CHANGE% > N) GOTO 7560
7610     PRINT "THE VALUE IS CURRENTLY ";CATCH(CHANGE%)
7620     INPUT "ENTER THE NEW VALUE ";CATCH(CHANGE%)
7630     IF (CATCH(CHANGE%) = 0# OR CATCH(CHANGE%) = 0! OR
CATCH(CHANGE%) = 0) THEN CFLAG%(CHANGE%) = 0 ELSE CFLAG%(CHANGE%) = 1
7640     PRINT " "
7650     GOTO 7560
7660 IF (CHOICE% <> 3) GOTO 7760
7670     PRINT "ENTER THE NUMBER OF THE ECOTROPHIC EFFICIENCY PARAMETER"
7680     PRINT "TO CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
7690     INPUT " ";CHANGE%
7700     IF (CHANGE% = 0) GOTO 7110
7710     IF (CHANGE% < 1 OR CHANGE% > N) GOTO 7670
7720     PRINT "THE VALUE IS CURRENTLY ";EE(CHANGE%)
7730     INPUT "ENTER THE NEW VALUE ";EE(CHANGE%)
7740     PRINT " "
7750     GOTO 7670
7760 IF (CHOICE% <> 3) GOTO 7860
7770     PRINT "ENTER THE NUMBER OF THE ECOTROPHIC EFFICIENCY PARAMETER"
7780     PRINT "TO CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
7790     INPUT " ";CHANGE%
7800     IF (CHANGE% = 0) GOTO 7110
7810     IF (CHANGE% < 1 OR CHANGE% > N) GOTO 7770
7820     PRINT "THE VALUE IS CURRENTLY ";EE(CHANGE%)
7830     INPUT "ENTER THE NEW VALUE ";EE(CHANGE%)
7840     PRINT " "
7850     GOTO 7770
7860 IF (CHOICE% <> 4) GOTO 8000
7870     PRINT "ENTER THE NUMBERS FOR THE DIET COMPOSITION PARAMETER TO"
7880     PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)"
7890     INPUT "ENTER THE ROW NUMBER (THE ITH ROW IN DC(I,J));IPARM%
7900     IF (IPARM% = 0) GOTO 7110
7910     IF (IPARM% < 1 OR IPARM% > N) GOTO 7890
7920     INPUT "ENTER THE COLUMN NUMBER (THE JTH COLUMN IN DC(I,J));JPARM%
7930     IF (JPARM% < 1 OR JPARM% > N) GOTO 7920
7940     PRINT " "
7950     PRINT "THE CURRENT VALUE FOR DC(";IPARM%;",";JPARM%) IS "
;DC(IPARM%,JPARM%)
7960     INPUT "ENTER THE NEW VALUE";DC(IPARM%,JPARM%)
7970     PRINT " "
7980     PRINT " "
7990     GOTO 7870
8000 IF (CHOICE% <> 5) GOTO 8100
8010     PRINT "ENTER THE NUMBER FOR THE PRODUCTION/BIOMASS PARAMETER TO"
8020     PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
8030     INPUT " ";CHANGE%
8040     IF (CHANGE% = 0) GOTO 7110
8050     IF (CHANGE% < 1 OR CHANGE% > N) GOTO 8010
8060     PRINT "THE VALUE IS CURRENTLY ";Z(CHANGE%)
8070     INPUT "ENTER THE NEW VALUE";Z(CHANGE%)
8080     PRINT " "
8090     GOTO 8010

```

Appendix I.--Continued.

```

8100 IF (CHOICE% <> 6) GOTO 8200
8110   PRINT "ENTER THE NUMBER FOR THE FOOD REQUIRED PARAMETER TO"
8120   PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
8130   INPUT " ";CHANGE%
8140   IF (CHANGE% = 0) GOTO 7110
8150   IF (CHANGE% < 1 OR CHANGE% > N) GOTO 8110
8160   PRINT "THE VALUE IS CURRENTLY ";FR(CHANGE%)
8170   INPUT "ENTER THE NEW VALUE";FR(CHANGE%)
8180   PRINT " "
8190   GOTO 8110
8200 IF (CHOICE% <> 7) GOTO 8300
8210   PRINT "ENTER THE NUMBER FOR THE HABITAT AREA PARAMETER TO"
8220   PRINT "CHANGE 0 -";N;" (ENTER 0 IF NO MORE TO BE CHANGED)";
8230   INPUT " ";CHANGE%
8240   IF (CHANGE% = 0) GOTO 7110
8250   IF (CHANGE% < 1 OR CHANGE% > N) GOTO 8110
8260   PRINT "THE VALUE IS CURRENTLY ";HABAR(CHANGE%)
8270   INPUT "ENTER THE NEW VALUE";HABAR(CHANGE%)
8280   PRINT " "
8290   GOTO 8210
8300 IF (CHOICE% <> 8) GOTO 7210
8310 PRINT " "
8320 PRINT " "
8330 INPUT "WOULD YOU LIKE TO SAVE THE INPUT PARAMETERS FROM THIS RUN (Y/N)"
;SAVEIT$
8340 IF (SAVEIT$ = "N") GOTO 8550
8350 IF (SAVEIT$ <> "Y") GOTO 8320
8360 INPUT "ENTER THE FILE NAME UNDER WHICH THIS RUN WILL BE SAVED ";FLNAME$
8370 PRINT "THE FILE NAME IS ";FLNAME$;" , IS THIS CORRECT (Y/N) ";
8380 INPUT " ";CORRECT$
8390 IF (CORRECT$ = "N") GOTO 8320
8400 IF (CORRECT$ <> "Y") GOTO 8320
8410 OPEN "O",#2,FLNAME$
8420 PRINT#2,N
8430 FOR I = 1 TO N
8440   B(I) = OLDB(I)
8450   CATCH(I) = OLDCATCH(I)
8460   PRINT#2,SPECIE$(I)
8470   PRINT#2,NFLAG(I),CFLAG%(I),CATCH(I),B(I),Z(I),EE(I),HABAR(I),FR(I)
8480 NEXT I
8490 FOR I = 1 TO N
8500   FOR J = 1 TO N
8510     PRINT#2,DC(I,J)
8520   NEXT J
8530 NEXT I
8540 PRINT "FILE ";FLNAME$;" HAS NOW BEEN SAVED"
8550 PRINT " "
8560 PRINT " "
8570 CLOSE
8580 PRINT "
***** END OF PROGRAM ECOPATH *****"
8590 END
8600 REM

```

Appendix I.--Continued.

```

8610 REM *****
8620 REM                                LOGICAL END OF PROGRAM
8630 REM *****
8640 REM
8650 REM =====
8660 REM SOLUTION TO A LINEAR EQUATIONS SUBROUTINE.
8670 REM
8680 REM METHOD USED:
8690 REM   THE METHOD OF SOLUTION IS BY ELIMINATION USING THE LARGEST PIVOTAL
8700 REM   DIVISOR.  EACH ITERATION INTERCHANGES THE ROWS REQUIRED TO AVOID
8710 REM   DIVISION BY 0 OR VERY SMALL ELEMENTS.  SUCCESSIVE SUBSTITUTION
8720 REM   YIELDS THE SOLUTION IN THE B VECTOR.  A CHECK IS MADE TO VERIFY
8730 REM   THAT THE MATRIX IS NOT SINGULAR.
8740 REM -----
8750 REM
8760 K = 1
8770 FOR I = 1 TO N
8780   FOR J = 1 TO N
8790     ARRAYA(K) = AA(J,I)
8800     K = K + 1
8810   NEXT J
8820 NEXT I
8830 TOL = 0!
8840 JJ = -N
8850 FOR J = 1 TO N
8860   JY = J + 1
8870   JJ = JJ + N + 1
8880   BIGA = 0#
8890   IT = JJ - J
8900   FOR I = J TO N
8910     REM
8920     REM SEARCH FOR THE MAXIMUM COEFFICIENT IN THE COLUMN
8930     REM -----
8940     IJ = IT + I
8950     IF ((ABS(BIGA) - ABS(ARRAYA(IJ))) >= 0#) GOTO 8980
8960     BIGA = ARRAYA(IJ)
8970     IMAX = I
8980   NEXT I
8990 REM
9000 REM TEST IF THE PIVOT IS LESS THAN THE TOLERANCE. CHECK FOR A SINGULAR
9010 REM MATRIX.  IF THE MATRIX IS SINGULAR, THE SOLUTION MAY NOT BE ACCURATE.
9020 REM -----
9030 REM
9040   IF ((ABS(BIGA) - TOL) > 0#) GOTO 9130
9050   PRINT " "
9060   PRINT " "
9070   PRINT "*****> WARNING: THE MATRIX IS SINGULAR"
9080   PRINT " "
9090   RETURN
9100 REM
9110 REM INTERCHANGE ROWS AS NEEDED
9120 REM -----

```


Appendix I.--Continued.

```

9130     IONE = J + N*(J - 2)
9140     IT = IMAX - J
9150     FOR K = J TO N
9160         IONE = IONE + N
9170         ITWO = IONE + IT
9180         SAVED = ARRAYA(IONE)
9190         ARRAYA(IONE) = ARRAYA(ITWO)
9200         ARRAYA(ITWO) = SAVED
9210 REM
9220 REM DIVIDE THE PIVOT ROW BY THE PIVOT COEFFICIENT
9230 REM -----
9240         ARRAYA(IONE) = ARRAYA(IONE)/BIGA
9250     NEXT K
9260 REM
9270     SAVED = B(IMAX)
9280     B(IMAX) = B(J)
9290     B(J) = SAVED/BIGA
9300 REM
9310     IF ((J - N) = 0#) GOTO 9440
9320     IQS = N*(J - 1)
9330     FOR IX = JY TO N
9340         IXJ = IQS + IX
9350         IT = J - IX
9360         FOR JX = JY TO N
9370             IXJX = N*(JX - 1) + IX
9380             JJX = IXJX + IT
9390             ARRAYA(IXJX) = ARRAYA(IXJX) - (ARRAYA(IXJ)*ARRAYA(JJX))
9400         NEXT JX
9410         B(IX) = B(IX) - (B(J)*ARRAYA(IXJ))
9420     NEXT IX
9430 NEXT J
9440 NY = N - 1
9450 IT = N*N
9460 FOR J = 1 TO NY
9470     IA = IT - J
9480     IB = N - J
9490     IC = N
9500     FOR K = 1 TO J
9510         B(IB) = B(IB) - ARRAYA(IA)*B(IC)
9520         IA = IA - N
9530         IC = IC - 1
9540     NEXT K
9550 NEXT J
9560 RETURN
9570 REM *****

```

Appendix II.--Sample run of the ECOPATH input program.

RUN

***** ECOPATH INPUT PARAMETER FILE PROGRAM *****

ENTER THE NAME OF THE FILE FOR THESE INPUT PARAMETERS ? DATA1
THE NAME OF THE FILE TO BE CREATED IS DATA1, IS THIS CORRECT (Y/N) ? Y

PLEASE ENTER THE NUMBER OF SPECIES GROUPS? 0

SORRY, THAT'S TOO SMALL.

PLEASE ENTER THE NUMBER OF SPECIES GROUPS? 2
THE NUMBER OF SPECIES GROUPS IS 2 , IS THIS CORRECT (Y/N) ? Y

ENTER THE NAME OF SPECIES GROUP 1 GROUP ONE
ENTER THE NAME OF SPECIES GROUP 2 GROUP # 2

ENTER '1' IF FIXED BIOMASS ESTIMATE, '0' IF NONE FOR GROUP ONE ? 2

1 OR 0 PLEASE

ENTER '1' IF FIXED BIOMASS ESTIMATE, '0' IF NONE FOR GROUP ONE ? 1
ENTER '1' IF FIXED BIOMASS ESTIMATE, '0' IF NONE FOR GROUP # 2 ? 0

ENTER THE KNOWN BIOMASS/HABITAT AREA FOR GROUP ONE ? 54.0

ENTER '1' IF CATCH DATA AVAILABLE, '0' IF NONE FOR GROUP ONE ? 0
ENTER '1' IF CATCH DATA AVAILABLE, '0' IF NONE FOR GROUP # 2 ? 9

1 OR 0 PLEASE

ENTER '1' IF CATCH DATA AVAILABLE, '0' IF NONE FOR GROUP # 2 ? 0

ENTER THE PRODUCTION/BIOMASS RATIO FOR GROUP ONE ? 5.4
ENTER THE PRODUCTION/BIOMASS RATIO FOR GROUP # 2 ? 6.5

ENTER THE ECOTROPHIC EFFICIENCY FOR GROUP ONE ? 0.85
ENTER THE ECOTROPHIC EFFICIENCY FOR GROUP # 2 ? 0.75

ENTER THE HABITAT AREA FOR GROUP ONE ? 1200
ENTER THE HABITAT AREA FOR GROUP # 2 ? 1200

ENTER THE FOOD REQUIRED FOR GROUP ONE ? 24.0
ENTER THE FOOD REQUIRED FOR GROUP # 2 ? 35.0

ENTER THE 2 DIET COMPOSITION PARAMETERS FOR GROUP ONE
ENTER DC(1 , 1) ? 0.9
ENTER DC(1 , 2) ? 0.1

ENTER THE 2 DIET COMPOSITION PARAMETERS FOR GROUP # 2

Appendix II.--Continued.

ENTER DC(2 , 1) ? .33
ENTER DC(2 , 2) ? .77

*** WARNING: THE DIET COMPOSITION FOR GROUP # 2
DOES NOT SUM TO 1 OR 0, PLEASE REENTER.

ENTER THE 2 DIET COMPOSITION PARAMETERS FOR GROUP # 2
ENTER DC(2 , 1) ? .33
ENTER DC(2 , 2) ? .67

ARE YOU SURE YOU WANT TO USE THE FILE NAME DATA1 (Y/N) ? N

ENTER THE DESIRED FILE NAME ? DATA

ARE YOU SURE YOU WANT TO USE THE FILE NAME DATA (Y/N) ? Y

****) CREATING FILE DATA
FILE DATA HAS BEEN CREATED.

***** END OF INPUT PROGRAM *****
Ok

Appendix III.--Sample run of the ECOPATH program using file "JEFF."

RUN

***** ECOPATH *****

PLEASE ENTER THE NAME OF THE FILE TO BE USED ? JEFF
 THE FILE TO BE USED IS JEFF, IS THIS CORRECT (Y/N) ? Y

ARE YOU USING A SCREEN OR A PRINTER (S/P) ? S

WOULD YOU LIKE TO MAKE ANY CHANGES TO THE INPUT VALUES NOW (Y/N)? N

SPECIES GROUPS

- 1 = BIRD
- 2 = SEAL
- 3 = TIGER SHARKS
- 4 = REEF SHARKS
- 5 = TURTLE
- 6 = SMALL PELAGIC
- 7 = JACK
- 8 = REEF FISHES
- 9 = LOBSTER & CRABS
- 10 = BOTTOM FISH
- 11 = TUNA
- 12 = ZOOPLANKTON
- 13 = PHYTOPLANKTON
- 14 = HETEROTROPHIC BENTHOS
- 15 = BENTHIC ALGAE

KNOWN BIOMASS/(WEIGHT/UNIT AREA OVER HABITAT AREA) (B)

1	2	3	4	5
15.000	63.000	42.000	0.000	0.000
6	7	8	9	10
0.000	0.000	0.000	0.000	0.000
11	12	13	14	15
0.000	0.000	0.000	0.000	0.000

TOTAL CATCH/(WEIGHT/UNIT AREA OVER HABITAT AREA) (CATCH)

1	2	3	4	5
0.000	0.000	0.000	0.000	0.000
6	7	8	9	10
0.000	0.000	0.000	0.000	0.000
11	12	13	14	15
0.000	0.000	0.000	0.000	0.000

Appendix III.--Continued.

ECOTROPHIC EFFICIENCY (FRACTION OF PRODUCTION CONSUMED BY PREDATORS) (EE)

1	2	3	4	5	6	7	8
0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
9	10	11	12	13	14	15	
0.950	0.950	0.950	0.950	0.950	0.950	0.950	

DIET COMPOSITION BY SPECIES GROUPS (DC)
(ROWS REPRESENT PREDATORS AND COLUMNS ARE PREY)

	1	2	3	4	5	6	8
BIRD	1	0.000	0.000	0.000	0.000	0.000	0.680
SEAL	2	0.000	0.000	0.000	0.000	0.000	0.000
TIGER SHARKS	3	0.300	0.080	0.010	0.030	0.010	0.080
REEF SHARKS	4	0.000	0.000	0.000	0.000	0.000	0.050
TURTLE	5	0.000	0.000	0.000	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.000	0.000	0.000	0.000	0.060
JACK	7	0.000	0.000	0.000	0.000	0.000	0.080
REEF FISHES	8	0.000	0.000	0.000	0.000	0.000	0.000
LOBSTER & CRABS	9	0.000	0.000	0.000	0.000	0.000	0.000
BOTTOM FISH	10	0.000	0.000	0.000	0.000	0.000	0.125
TUNA	11	0.000	0.000	0.000	0.000	0.000	0.480
ZOOPLANKTON	12	0.000	0.000	0.000	0.000	0.000	0.000
PHYTOPLANKTON	13	0.000	0.000	0.000	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000	0.000	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000	0.000	0.000	0.000

	7	8	9	10	11	12
BIRD	1	0.100	0.150	0.000	0.000	0.050
SEAL	2	0.000	0.850	0.150	0.000	0.000
TIGER SHARKS	3	0.050	0.280	0.140	0.000	0.000
REEF SHARKS	4	0.000	0.900	0.050	0.000	0.000
TURTLE	5	0.000	0.000	0.000	0.000	0.100
SMALL PELAGIC	6	0.000	0.000	0.000	0.000	0.940
JACK	7	0.000	0.800	0.120	0.000	0.000
REEF FISHES	8	0.000	0.123	0.000	0.000	0.170
LOBSTER & CRABS	9	0.000	0.000	0.000	0.000	0.021
BOTTOM FISH	10	0.000	0.469	0.018	0.026	0.104
TUNA	11	0.000	0.080	0.000	0.080	0.360
ZOOPLANKTON	12	0.000	0.000	0.000	0.000	0.000
PHYTOPLANKTON	13	0.000	0.000	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000	0.000	0.000

	13	14	15	SUM
BIRD	1	0.000	0.000	1.00
SEAL	2	0.000	0.000	1.00
TIGER SHARKS	3	0.000	0.000	1.00
REEF SHARKS	4	0.000	0.000	1.00
TURTLE	5	0.000	0.000	1.00
SMALL PELAGIC	6	0.000	0.000	1.00
JACK	7	0.000	0.000	1.00
REEF FISHES	8	0.000	0.459	1.00
LOBSTER & CRABS	9	0.000	0.979	1.00
BOTTOM FISH	10	0.000	0.258	1.00
TUNA	11	0.000	0.000	1.00
ZOOPLANKTON	12	0.910	0.000	1.00
PHYTOPLANKTON	13	0.000	0.000	0.00
HETEROTROPHIC B	14	0.000	0.150	1.00
BENTHIC ALGAE	15	0.000	0.000	0.00

Appendix III.--Continued.

PRODUCTION/BIOMASS RATIO ($Z = M + F$)

1	2	3	4	5
5.400	3.000	0.500	0.175	0.150
6	7	8	9	10
1.100	0.350	1.500	0.520	0.320
11	12	13	14	15
0.660	40.000	70.000	3.000	12.500

ANNUAL FOOD REQUIRED AS A FRACTION OF THE MEAN ANNUAL BIOMASS (FR)

1	2	3	4	5
80.000	40.000	4.500	3.800	3.500
6	7	8	9	10
7.500	3.800	9.500	8.200	3.600
11	12	13	14	15
5.300	280.000	0.000	12.500	0.000

HABITAT AREA (HABAR)

1	2	3	4	5
1200.000	1200.000	1200.000	1200.000	1200.000
6	7	8	9	10
1200.000	1200.000	700.000	700.000	300.000
11	12	13	14	15
900.000	1200.000	1200.000	700.000	700.000

Appendix III.--Continued.

INITIAL EQUILIBRIUM

BIOMASS RECALCULATED PER HABITAT AREA FOR OUTPUT

		BIOMASS PER UNIT OF HABITAT AREA	ANNUAL PRODUCTION PER UNIT HABITAT AREA	FISHERY CATCH PER UNIT OF HABITAT AREA	HABITAT AREA	ECOLOGICAL EFFICIENCY (PRODUCTION/ CONSUMPTION)
BIRD	1	15	81	0	1200	0.0675
SEAL	2	63	189	0	1200	0.0750
TIGER SHARKS	3	42	21	0	1200	0.1111
REEF SHARKS	4	34	6	0	1200	0.0461
TURTLE	5	13	2	0	1200	0.0429
SMALL PELAGIC	6	1864	2050	0	1200	0.1467
JACK	7	389	136	0	1200	0.0921
REEF FISHES	8	25695	38543	0	700	0.1579
LOBSTER & CRABS	9	2062	1072	0	700	0.0634
BOTTOM FISH	10	357	114	0	300	0.0889
TUNA	11	59	39	0	900	0.1245
ZOOPLANKTON	12	993	39721	0	1200	0.1429
PHYTOPLANKTON	13	3805	266342	0	1200	0.0000
HETEROTROPHIC B	14	132042	396126	0	700	0.2400
BENTHIC ALGAE	15	126859	1585741	0	700	0.0000

CONSUMPTION VECTOR (BIOMASS/HABITAT AREA)
(COLUMNS REPRESENT PERDATOR, ROWS REPRESENT PREY)

		1	2	3
BIRD	1	0.00	0.00	56.70
SEAL	2	0.00	0.00	15.12
TIGER SHARKS	3	0.00	0.00	1.89
REEF SHARKS	4	0.00	0.00	5.67
TURTLE	5	0.00	0.00	1.89
SMALL PELAGIC	6	816.00	0.00	15.12
JACK	7	120.00	0.00	9.45
REEF FISHES	8	180.00	2,142.00	52.92
LOBSTER & CRABS	9	0.00	378.00	26.46
BOTTOM FISH	10	0.00	0.00	0.00
TUNA	11	24.00	0.00	3.78
ZOOPLANKTON	12	60.00	0.00	0.00
PHYTOPLANKTON	13	0.00	0.00	0.00
HETEROTROPHIC B	14	0.00	0.00	0.00
BENTHIC ALGAE	15	0.00	0.00	0.00
TOTAL		1,200.00	2,520.00	189.00

Appendix III.--Continued.

		4	5	6
BIRD	1	0.00	0.00	0.00
SEAL	2	0.00	0.00	0.00
TIGER SHARKS	3	0.00	0.00	0.00
REEF SHARKS	4	0.00	0.00	0.00
TURTLE	5	0.00	0.00	0.00
SMALL PELAGIC	6	6.48	0.00	838.62
JACK	7	0.00	0.00	0.00
REEF FISHES	8	116.64	0.00	0.00
LOBSTER & CRABS	9	6.48	0.00	0.00
BOTTOM FISH	10	0.00	0.00	0.00
TUNA	11	0.00	0.00	0.00
ZOOPLANKTON	12	0.00	4.64	13,138.45
PHYTOPLANKTON	13	0.00	0.00	0.00
HETEROTROPHIC B	14	0.00	0.00	0.00
BENTHIC ALGAE	15	0.00	41.78	0.00
TOTAL		129.60	46.42	13,977.08
		7	8	9
BIRD	1	0.00	0.00	0.00
SEAL	2	0.00	0.00	0.00
TIGER SHARKS	3	0.00	0.00	0.00
REEF SHARKS	4	0.00	0.00	0.00
TURTLE	5	0.00	0.00	0.00
SMALL PELAGIC	6	118.35	0.00	0.00
JACK	7	0.00	0.00	0.00
REEF FISHES	8	1,183.54	30,024.81	0.00
LOBSTER & CRABS	9	177.53	0.00	0.00
BOTTOM FISH	10	0.00	0.00	0.00
TUNA	11	0.00	0.00	0.00
ZOOPLANKTON	12	0.00	41,497.70	355.11
PHYTOPLANKTON	13	0.00	0.00	0.00
HETEROTROPHIC B	14	0.00	112,043.79	16,554.93
BENTHIC ALGAE	15	0.00	60,537.82	0.00
TOTAL		1,479.43	244,104.11	16,910.04
		10	11	12
BIRD	1	0.00	0.00	0.00
SEAL	2	0.00	0.00	0.00
TIGER SHARKS	3	0.00	0.00	0.00
REEF SHARKS	4	0.00	0.00	0.00
TURTLE	5	0.00	0.00	0.00
SMALL PELAGIC	6	160.72	150.29	0.00
JACK	7	0.00	0.00	0.00
REEF FISHES	8	603.00	25.05	0.00
LOBSTER & CRABS	9	23.14	0.00	0.00
BOTTOM FISH	10	33.43	25.05	0.00
TUNA	11	0.00	0.00	0.00
ZOOPLANKTON	12	133.72	112.72	0.00
PHYTOPLANKTON	13	0.00	0.00	253,024.44
HETEROTROPHIC B	14	331.72	0.00	0.00
BENTHIC ALGAE	15	0.00	0.00	25,024.39
TOTAL		1,285.72	313.10	278,048.83

Appendix III.--Continued.

		13	14	15
BIRD	1	0.00	0.00	0.00
SEAL	2	0.00	0.00	0.00
TIGER SHARKS	3	0.00	0.00	0.00
REEF SHARKS	4	0.00	0.00	0.00
TURTLE	5	0.00	0.00	0.00
SMALL PELAGIC	6	0.00	0.00	0.00
JACK	7	0.00	0.00	0.00
REEF FISHES	8	0.00	0.00	0.00
LOBSTER & CRABS	9	0.00	0.00	0.00
BOTTOM FISH	10	0.00	0.00	0.00
TUNA	11	0.00	0.00	0.00
ZOOPLANKTON	12	0.00	0.00	0.00
PHYTOPLANKTON	13	0.00	0.00	0.00
HETEROTROPHIC B	14	0.00	247,578.61	0.00
BENTHIC ALGAE	15	0.00	1,402,945.43	0.00
TOTAL		0.00	1,650,524.04	0.00

C VECTOR

1	2	3	4	5
18000.000	75600.000	50400.000	6804.000	2268.000
6	7	8	9	10
997344.000	155340.000	2849904.000	485352.000	0.000
11	12	13	14	15
33336.000	72000.000	0.000	0.000	0.000

AA MATRIX

	1	2	3	4
BIRD	1	1.000	0.000	0.000
SEAL	2	0.000	1.000	0.000
TIGER SHARKS	3	0.000	0.000	1.000
REEF SHARKS	4	0.000	0.000	0.000
TURTLE	5	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.000	0.000
JACK	7	0.000	0.000	0.000
REEF FISHES	8	0.000	0.000	0.000
LOBSTER & CRABS	9	0.000	0.000	0.000
BOTTOM FISH	10	0.000	0.000	0.000
TUNA	11	0.000	0.000	0.000
ZOOPLANKTON	12	0.000	0.000	0.000
PHYTOPLANKTON	13	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000

Appendix III.--Continued.

		5	6	7	8
BIRD	1	0.000	0.000	0.000	0.000
SEAL	2	0.000	0.000	0.000	0.000
TIGER SHARKS	3	0.000	0.000	0.000	0.000
REEF SHARKS	4	0.000	0.000	0.000	0.000
TURTLE	5	0.143	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.595	-0.304	0.000
JACK	7	0.000	0.000	0.333	0.000
REEF FISHES	8	0.000	0.000	-3.040	0.256
LOBSTER & CRABS	9	0.000	0.000	-0.456	0.000
BOTTOM FISH	10	0.000	0.000	0.000	0.000
TUNA	11	0.000	0.000	0.000	0.000
ZOOPLANKTON	12	-0.350	-7.050	0.000	-1.615
PHYTOPLANKTON	13	0.000	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000	-4.361
BENTHIC ALGAE	15	-3.150	0.000	0.000	-2.356
		9	10	11	12
BIRD	1	0.000	0.000	0.000	0.000
SEAL	2	0.000	0.000	0.000	0.000
TIGER SHARKS	3	0.000	0.000	0.000	0.000
REEF SHARKS	4	0.000	0.000	0.000	0.000
TURTLE	5	0.000	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	-0.450	-2.544	0.000
JACK	7	0.000	0.000	0.000	0.000
REEF FISHES	8	0.000	-1.688	-0.424	0.000
LOBSTER & CRABS	9	0.494	-0.065	0.000	0.000
BOTTOM FISH	10	0.000	0.210	-0.424	0.000
TUNA	11	0.000	0.000	0.627	0.000
ZOOPLANKTON	12	-0.172	-0.374	-1.908	38.000
PHYTOPLANKTON	13	0.000	0.000	0.000	-254.800
HETEROTROPHIC B	14	-8.028	-0.929	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000	-25.200
		13	14	15	
BIRD	1	0.000	0.000	0.000	
SEAL	2	0.000	0.000	0.000	
TIGER SHARKS	3	0.000	0.000	0.000	
REEF SHARKS	4	0.000	0.000	0.000	
TURTLE	5	0.000	0.000	0.000	
SMALL PELAGIC	6	0.000	0.000	0.000	
JACK	7	0.000	0.000	0.000	
REEF FISHES	8	0.000	0.000	0.000	
LOBSTER & CRABS	9	0.000	0.000	0.000	
BOTTOM FISH	10	0.000	0.000	0.000	
TUNA	11	0.000	0.000	0.000	
ZOOPLANKTON	12	0.000	0.000	0.000	
PHYTOPLANKTON	13	66.500	0.000	0.000	
HETEROTROPHIC B	14	0.000	0.975	0.000	
BENTHIC ALGAE	15	0.000	-10.625	11.875	

WOULD YOU LIKE TO CHANGE ANY INPUT PARAMETERS (Y/N)? N

WOULD YOU LIKE TO SAVE THE INPUT PARAMETERS FROM THIS RUN (Y/N)? N

***** END OF PROGRAM ECOPATH *****

OK

Appendix IV.--Changing an input parameter value.

RUN

***** E C O P A T H *****

PLEASE ENTER THE NAME OF THE FILE TO BE USED ? JEFF
 THE FILE TO BE USED IS JEFF, IS THIS CORRECT (Y/N) ? Y

ARE YOU USING A SCREEN OR A PRINTER (S/P) ? S

WOULD YOU LIKE TO MAKE ANY CHANGES TO THE INPUT VALUES NOW (Y/N)? Y

- 1 = KNOWN BIOMASS/HABITAT AREA (B)
- 2 = TOTAL CATCH/HABITAT AREA (CATCH)
- 3 = ECOTROPHIC EFFICIENCY (EE)
- 4 = DIET COMPOSITION (DC)
- 5 = PRODUCTION/BIOMASS RATIO ($Z = M + F$)
- 6 = FOOD REQUIRED (FRACTION OF MEAN ANNUAL BIOMASS) (FR)
- 7 = HABITAT AREA (HABAR)
- 8 = NO MORE CHANGES TO BE MADE (MAKE ANOTHER PASS)

ENTER THE NUMBER OF YOUR CHOICE (1-8)? 3

1	2	3	4
BIRD	SEAL	TIGER SHARKS	REEF SHARKS
5	6	7	8
TURTLE	SMALL PELAGIC	JACK	REEF FISHES
9	10	11	12
LOBSTER & CRABS	BOTTOM FISH	TUNA	ZOOPLANKTON
13	14	15	
PHYTOPLANKTON	HETEROTROPHIC & BENTHIC ALGAE		

ENTER THE NUMBER OF THE ECOTROPHIC EFFICIENCY PARAMETER
 TO CHANGE 0 - 15 (ENTER 0 IF NO MORE TO BE CHANGED) ? 3
 THE VALUE IS CURRENTLY .95
 ENTER THE NEW VALUE ? .75

ENTER THE NUMBER OF THE ECOTROPHIC EFFICIENCY PARAMETER
 TO CHANGE 0 - 15 (ENTER 0 IF NO MORE TO BE CHANGED) ? 0

- 1 = KNOWN BIOMASS/HABITAT AREA (B)
- 2 = TOTAL CATCH/HABITAT AREA (CATCH)
- 3 = ECOTROPHIC EFFICIENCY (EE)
- 4 = DIET COMPOSITION (DC)
- 5 = PRODUCTION/BIOMASS RATIO ($Z = M + F$)
- 6 = FOOD REQUIRED (FRACTION OF MEAN ANNUAL BIOMASS) (FR)
- 7 = HABITAT AREA (HABAR)
- 8 = NO MORE CHANGES TO BE MADE (MAKE ANOTHER PASS)

ENTER THE NUMBER OF YOUR CHOICE (1-8)?

Appendix V.--AA matrix warning message.

HABITAT AREA (HABAR)

1	2	3	4	5
1200.000	1200.000	1200.000	1200.000	1200.000
6	7	8	9	10
1200.000	1200.000	700.000	700.000	300.000
11	12	13	14	15
900.000	1200.000	1200.000	700.000	700.000

** WARNING :THE DIAGONAL ENTRIES IN THE AA MATRIX ARE NOT
POSITIVE FOR THE FOLLOWING SPECIES GROUPS:

SPECIES GROUP	LOCATION	VALUE
BOTTOM FISH--	AA(10,10)	-0.093----

*** NOTE: THE ABOVE INDICATES THAT PREDATION PLUS FISHING (AS APPLICABLE)
IS EXCEEDING PRODUCTION. THE EQUALIBRIUM BIOMASS ESTIMATES
AS A RESULT, ARE NEGATIVE. THEREFORE, THE
EQUALIBRIUM BIOMASS OUTPUT HAS BEEN SUPPRESSED.

PLEASE CHECK THE INPUT VALUES OF: DIET COMPOSITION,
PRODUCTION/BIOMASS, AND FOOD REQUIREMENTS FOR THE
SPECIES GROUPS LISTED ABOVE AND RERUN THE PROGRAM.

THE AA MATRIX

	1	2	3	4
BIRD	1	1.000	0.000	0.000
SEAL	2	0.000	1.000	0.000
TIGER SHARKS	3	0.000	0.000	1.000
REEF SHARKS	4	0.000	0.000	0.000
TURTLE	5	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.000	0.000
JACK	7	0.000	0.000	0.000
REEF FISHES	8	0.000	0.000	0.000
LOBSTER & CRABS	9	0.000	0.000	0.000
BOTTOM FISH	10	0.000	0.000	0.000
TUNA	11	0.000	0.000	0.000
ZOOPLANKTON	12	0.000	0.000	0.000
PHYTOPLANKTON	13	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000

Appendix V.--Continued.

		5	6	7	8
BIRD	1	0.000	0.000	0.000	0.000
SEAL	2	0.000	0.000	0.000	0.000
TIGER SHARKS	3	0.000	0.000	0.000	0.000
REEF SHARKS	4	0.000	0.000	0.000	0.000
TURTLE	5	0.143	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.595	-0.304	0.000
JACK	7	0.000	0.000	0.333	0.000
REEF FISHES	8	0.000	0.000	-3.040	0.256
LOBSTER & CRABS	9	0.000	0.000	-0.456	0.000
BOTTOM FISH	10	0.000	0.000	0.000	0.000
TUNA	11	0.000	0.000	0.000	0.000
ZOOPLANKTON	12	-0.350	-7.050	0.000	-1.615
PHYTOPLANKTON	13	0.000	0.000	0.000	0.000
HETEROTROPHIC B	14	0.000	0.000	0.000	-4.361
BENTHIC ALGAE	15	-3.150	0.000	0.000	-2.356

		9	10	11	12
BIRD	1	0.000	0.000	0.000	0.000
SEAL	2	0.000	0.000	0.000	0.000
TIGER SHARKS	3	0.000	0.000	0.000	0.000
REEF SHARKS	4	0.000	0.000	0.000	0.000
TURTLE	5	0.000	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	-0.450	-2.544	0.000
JACK	7	0.000	0.000	0.000	0.000
REEF FISHES	8	0.000	-1.688	-0.424	0.000
LOBSTER & CRABS	9	0.494	-0.065	0.000	0.000
BOTTOM FISH	10	0.000	-0.093	-0.424	0.000
TUNA	11	0.000	0.000	0.627	0.000
ZOOPLANKTON	12	-0.172	-0.374	-1.908	38.000
PHYTOPLANKTON	13	0.000	0.000	0.000	-254.800
HETEROTROPHIC B	14	-8.028	-0.929	0.000	0.000
BENTHIC ALGAE	15	0.000	0.000	0.000	-25.200

		13	14	15
BIRD	1	0.000	0.000	0.000
SEAL	2	0.000	0.000	0.000
TIGER SHARKS	3	0.000	0.000	0.000
REEF SHARKS	4	0.000	0.000	0.000
TURTLE	5	0.000	0.000	0.000
SMALL PELAGIC	6	0.000	0.000	0.000
JACK	7	0.000	0.000	0.000
REEF FISHES	8	0.000	0.000	0.000
LOBSTER & CRABS	9	0.000	0.000	0.000
BOTTOM FISH	10	0.000	0.000	0.000
TUNA	11	0.000	0.000	0.000
ZOOPLANKTON	12	0.000	0.000	0.000
PHYTOPLANKTON	13	66.500	0.000	0.000
HETEROTROPHIC B	14	0.000	0.975	0.000
BENTHIC ALGAE	15	0.000	-10.625	11.875

WOULD YOU LIKE TO CHANGE ANY INPUT PARAMETERS (Y/N)? N

WOULD YOU LIKE TO SAVE THE INPUT PARAMETERS FROM THIS RUN (Y/N)? N

***** END OF PROGRAM ECOPATH *****

Ok

Appendix VI.--Diet composition warning message.

ECOTROPHIC EFFICIENCY (FRACTION OF PRODUCTION CONSUMED BY PREDATORS) (EE)

1	2	3	4	5	6	7	8
0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
9	10	11	12	13	14	15	
0.950	0.950	0.950	0.950	0.950	0.950	0.950	

*** WARNING: THE DIET COMPOSITION FOR THE FOLLOW SPECIES
 DOES NOT SUM TO 1 OR 0, PLEASE VERIFY DC INPUT
 REEF FISHES

WOULD YOU LIKE TO CHANGE ANY INPUT PARAMETERS (Y/N)? N

WOULD YOU LIKE TO SAVE THE INPUT PARAMETERS FROM THIS RUN (Y/N)? N

***** END OF PROGRAM ECOPATH *****

Ok

83-24

SOUTHWEST FISHERIES CENTER

HONOLULU, HI 96812

P.O. BOX 3830

November 1983

HONOLULU LABORATORY

LIBRARY

JAN 18 1984

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

NATIONAL MARINE FISHERIES SERVICE

ANNUAL AND AVERAGE MONTHLY TRENDS IN CATCH OF LARGE PELAGIC SPECIES IN HAWAII 1949-78

Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

Not for Publication

ADMINISTRATIVE REPORT H-83-24

INTRODUCTION

Guidelines for the preparation of fishery management plans under the Magnuson Fishery Conservation and Management Act call for a basic description of the fishery covered by the plan. This data summary (estimates of catch and value for billfishes, mahimahi, wahoo, and sharks) was prepared for the Pelagic Species Plan Development Team from the monthly reports of commercial fish landings prepared by the Hawaii Division of Aquatic Resources (HDAR). Estimates for tunas are also included for comparative purposes.

ANNUAL TRENDS

The data have been summarized to show annual historical trends over the years 1949-78; data for 1979 seem to be incomplete while those for more recent years have not been released by HDAR. The tables include reported catch (actual landings) in thousands of pounds and metric tons, reported revenue in thousands of dollars, deflated revenue in thousands of dollars (adjusted to 1967 base year prices using the Consumer Price Index), and adjusted revenue in thousands of dollars (inflated to December 1981 Consumer Price Index for Honolulu).¹ Figure 1 presents catch in thousands of pounds (C) and adjusted revenue in thousands of dollars (R). For total billfishes (Table 1-A and Figure 1-A), there is an obvious downward trend in catches, and this is confirmed by a simple linear regression with a negative slope and an "F" value of 46.9 which is significant at the 0.0001 probability level. There is also a significant quadratic component indicating that the trend is concave upwards. There was a significant linear trend for black, blue, and striped marlins, swordfish, and mahimahi (Figures 1-B, 1-C, 1-F, 1-G, and 1-H, respectively). That concave shape, a significant quadratic effect, was apparent for blue marlin and mahimahi. Wahoo (Figure 1-I) exhibited a significant positive linear trend. In contrast to the billfish, only bigeye tuna and "combined tunas" (Figures 1-J and 1-L, respectively) exhibit a significant negative linear trend. There is a significant quadratic effect for yellowfin tuna and kawakawa (Figures 1-M and 1-R, respectively); the quadratic effect was borderline for bigeye tuna. The increase of ika shibi fishing in the late 1970's probably contributed to the increased catches of yellowfin and bigeye tunas.

MONTHLY TRENDS

Seasonal variation is shown in monthly averages over the 1949-78 period. Table 2 contains reported catch (actual landings) in thousands of pounds and metric tons, as well as reported revenue, deflated revenue, and adjusted revenue in thousands of dollars. Figure 2 presents catch in thousands of pounds (C) and reported revenue in thousands of dollars (R).

¹The tables and figures were prepared by Wesley Higuchi, Mathematics Aid, under the direction of Samuel G. Pooley, Industry Economist, in the Fishery Management Program.

The monthly trend indicates that all billfishes (Figure 2-A) are nearly equally abundant except for January when there is a marked low. However, the individual species show considerable variation. Black marlin (Figure 2-B) shows a peak in May while blue marlin (Figure 2-C) catches increase in May, peak in August, and all disappear by November. Swordfish (Figure 2-G) shows a similar pattern but the peak occurs earlier, in May and June. Sailfish, shortbill spearfish, and striped marlin (Figures 2-D, 2-E, and 2-F, respectively) show high catches in late winter and spring, and lowest catches in the summer. Mahimahi (Figure 2-H) exhibits a bimodal seasonal pattern with peaks in March-April and October. Wahoo (Figure 2-I) catches peak in the summer.

The catch of total tunas (Figure 2-L) peaks in the summer and is primarily due to skipjack and yellowfin tunas (Figures 2-M and 2-P, respectively). Albacore (Figure 2-Q) seems to have a regular seasonal cycle: the catch peaks in September. Bigeye tuna (Figure 2-O) follows a pattern of a peak in the midwinter period. Kawakawa (Figure 2-R) catches seem to be highest in the winter, but as with many of the species there is a low point in January.

Table 1-A.--Billfishes. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	1020.6	462.9	367.26	570.10	1446.91
1950	1286.7	583.5	324.05	484.39	1229.37
1951	1138.7	516.4	342.75	482.75	1225.21
1952	957.7	434.3	309.87	423.90	1075.85
1953	983.2	445.5	226.74	307.66	780.83
1954	1063.0	482.1	184.18	247.55	628.23
1955	787.2	357.0	184.72	244.99	621.79
1956	753.4	341.7	169.76	222.20	563.93
1957	628.7	285.1	168.64	213.47	541.80
1958	724.9	328.7	164.12	198.21	503.06
1959	678.3	307.6	181.43	215.47	546.86
1960	594.7	265.2	167.84	194.49	493.61
1961	541.7	245.7	148.50	167.61	425.33
1962	511.9	232.2	134.59	148.55	377.02
1963	554.3	251.4	159.25	171.97	436.47
1964	717.4	325.3	187.19	201.50	511.41
1965	590.0	267.6	169.77	179.46	455.46
1966	512.0	232.2	161.42	165.90	421.05
1967	580.2	263.1	197.02	197.02	500.03
1968	546.9	248.0	226.39	218.10	553.53
1969	488.2	221.4	266.47	245.60	623.33
1970	583.2	264.5	291.84	255.55	648.58
1971	310.4	140.8	147.17	123.77	314.14
1972	229.2	103.9	114.59	93.32	236.84
1973	230.9	104.7	108.89	84.87	215.40
1974	323.1	146.5	121.88	85.89	218.00
1975	347.2	157.5	148.33	95.69	242.87
1976	418.6	189.5	175.68	107.91	273.89
1977	520.8	236.2	284.52	165.61	420.32
1978	740.8	336.0	441.95	239.15	606.96
AVERAGE	645.1	292.6	210.23	225.09	571.27

Table 1-B. Black marlin. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	10.8	4.9	1.97	2.94	7.46
1951	10.1	4.6	2.87	4.04	10.24
1952	8.2	3.7	2.36	3.23	5.19
1953	10.1	4.6	2.10	2.85	7.24
1954	11.3	5.1	1.41	1.89	4.80
1955	18.5	8.4	3.22	4.29	10.86
1956	15.7	7.1	3.37	4.41	11.20
1957	18.2	8.2	4.10	5.19	13.18
1958	27.2	12.3	5.46	6.60	16.75
1959	18.1	8.2	3.88	4.61	11.69
1960	9.5	4.3	2.58	2.99	7.59
1961	16.2	7.4	4.91	5.54	14.07
1962	21.0	9.5	5.87	6.48	16.44
1963	1.4	0.6	0.58	0.63	1.59
1964	6.0	2.7	2.14	2.31	5.85
1965	3.4	1.6	1.15	1.21	3.08
1966	12.4	5.6	4.52	4.65	11.79
1967	4.9	2.2	1.83	1.83	4.65
1968	4.5	2.0	2.91	2.81	7.13
1969	1.5	0.7	0.94	0.87	2.20
1970	1.5	0.7	1.01	0.89	2.25
1971	4.0	1.8	1.64	1.38	3.51
1972	0.5	0.2	0.01	0.01	0.03
1973	1.4	0.7	0.52	0.40	1.03
1974	0.9	0.4	0.99	0.70	1.77
1975	0.6	0.3	0.42	0.27	0.69
1976	.	.	.	.	.
1977	8.0	3.6	2.56	1.49	3.78
1978	1.4	0.6	0.43	0.23	0.60
AVERAGE	8.8	4.0	2.35	2.67	6.77

Table 1-C.--Blue marlin. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	•	•	•	•	•
1950	534.9	242.6	154.05	230.27	584.43
1951	599.7	272.0	189.17	266.44	676.22
1952	526.3	238.7	179.17	245.10	622.06
1953	577.4	261.8	135.48	183.83	466.55
1954	806.7	365.9	137.20	184.41	468.03
1955	472.1	214.1	108.88	144.40	366.50
1956	471.0	213.6	102.96	134.77	342.04
1957	327.3	148.4	80.94	102.45	260.02
1958	304.5	138.1	67.48	81.49	206.83
1959	379.3	172.0	100.94	119.88	304.26
1960	317.4	143.9	90.46	104.82	266.02
1961	271.0	122.9	75.33	85.02	215.79
1962	183.0	83.0	49.97	55.15	139.98
1963	190.3	86.3	56.16	60.65	153.92
1964	174.6	79.2	47.91	51.57	130.89
1965	171.8	77.9	44.58	47.13	119.61
1966	147.4	66.9	43.97	45.19	114.69
1967	145.3	65.9	40.69	40.69	103.28
1968	104.8	47.5	36.95	35.60	90.36
1969	149.3	67.7	57.92	53.39	135.49
1970	222.3	100.8	68.96	60.39	153.26
1971	111.2	50.4	21.88	18.40	46.71
1972	55.2	25.0	0.34	0.28	0.70
1973	83.6	37.9	12.89	10.05	25.49
1974	124.8	56.6	22.89	16.13	40.94
1975	104.8	47.5	24.47	15.79	40.07
1976	191.2	86.7	52.30	32.13	81.54
1977	366.2	166.1	109.51	63.75	161.79
1978	537.3	243.7	206.10	111.52	293.05
AVERAGE	298.3	135.3	79.98	89.68	227.60

Table 1-D.--Sailfish. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	1020.6	462.9	397.36	570.10	1446.91
1950	114.6	52.0	27.76	41.49	105.31
1951	71.9	32.6	23.68	33.35	84.65
1952	21.4	9.7	6.38	8.73	22.15
1953	19.8	9.0	4.49	6.09	15.47
1954	11.3	5.1	1.78	2.40	6.09
1955	6.3	2.9	1.16	1.54	3.90
1956	9.7	4.4	1.47	1.92	4.87
1957	7.8	3.6	1.50	1.91	4.84
1958	16.9	7.6	2.61	3.15	8.00
1959	18.2	8.3	2.36	2.80	7.11
1960	9.1	4.1	1.98	2.30	5.83
1961	4.6	2.1	0.82	0.92	2.34
1962	5.7	2.6	0.90	1.00	2.54
1963	5.9	2.7	0.93	1.01	2.56
1964	11.3	5.1	1.57	1.69	4.29
1965	10.5	4.9	1.73	1.83	4.65
1966	16.2	7.3	2.58	2.65	6.73
1967	19.4	8.8	3.35	3.35	8.51
1968	12.6	5.7	2.49	2.40	6.09
1969	6.2	2.8	2.54	2.34	5.94
1970	2.7	1.2	0.49	0.43	1.08
1971	1.0	0.5	0.31	0.26	0.67
1972	1.0	0.4	0.34	0.28	0.71
1973	1.5	0.7	0.45	0.35	0.89
1974	0.9	0.4	0.21	0.15	0.38
1975	0.2	0.1	0.11	0.07	0.19
1976	1.7	0.8	0.45	0.28	0.71
1977	1.2	0.6	0.95	0.55	1.40
1978	0.3	0.1	0.07	0.04	0.10
AVERAGE	47.7	21.6	16.43	23.18	58.83

Table 1-E.--Shortbill spearfish. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	•	•	•	•	•
1950	•	•	•	•	•
1951	•	•	•	•	•
1952	•	•	•	•	•
1953	•	•	•	•	•
1954	•	•	•	•	•
1955	•	•	•	•	•
1956	•	•	•	•	•
1957	•	•	•	•	•
1958	•	•	•	•	•
1959	•	•	•	•	•
1960	•	•	•	•	•
1961	•	•	•	•	•
1962	•	•	•	•	•
1963	•	•	•	•	•
1964	•	•	•	•	•
1965	•	•	•	•	•
1966	•	•	•	•	•
1967	•	•	•	•	•
1968	•	•	•	•	•
1969	•	•	•	•	•
1970	•	•	•	•	•
1971	•	•	•	•	•
1972	•	•	•	•	•
1973	•	•	•	•	•
1974	•	•	•	•	•
1975	6.8	3.1	2.81	1.81	4.60
1976	13.7	6.2	7.37	4.53	11.49
1977	12.8	5.8	6.37	3.71	9.41
1978	24.7	11.2	19.71	10.66	27.06
AVERAGE	14.5	6.6	9.06	5.18	13.14

Table 1-F.--Striped marlin. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949					
1950	566.4	256.9	126.12	188.52	478.47
1951	380.6	172.6	107.55	151.48	384.46
1952	363.0	164.6	110.99	151.83	385.35
1953	357.9	162.3	81.82	111.01	281.75
1954	204.9	92.9	39.20	52.69	133.72
1955	242.3	109.9	63.05	83.62	212.23
1956	224.5	101.8	55.54	72.70	184.52
1957	244.4	110.9	76.25	96.52	244.98
1958	348.6	158.1	84.78	102.39	259.86
1959	242.6	110.0	70.09	83.24	211.27
1960	217.8	98.8	66.57	77.13	195.76
1961	226.7	102.8	63.03	71.14	180.54
1962	276.6	125.5	73.77	81.43	206.66
1963	334.4	151.7	97.64	105.44	267.62
1964	501.8	227.6	131.60	141.65	359.52
1965	385.0	174.6	118.29	125.05	317.37
1966	318.3	144.4	105.96	108.90	276.40
1967	398.1	180.6	148.72	148.72	377.45
1968	413.6	187.6	181.76	175.11	444.43
1969	317.2	143.9	202.37	186.52	473.38
1970	344.8	156.4	217.86	190.77	484.18
1971	191.3	86.8	122.51	103.03	261.50
1972	171.8	77.9	113.71	92.60	235.01
1973	141.8	64.3	94.48	73.64	186.89
1974	196.2	89.0	97.56	68.75	174.50
1975	234.1	106.2	120.24	77.57	196.88
1976	209.0	94.8	113.96	70.00	177.66
1977	91.3	41.4	97.21	56.58	143.60
1978	147.0	66.7	174.65	94.51	239.87
AVERAGE	285.9	129.7	108.87	108.36	275.03

Table 1-G.--Swordfish (broadbill). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	28.7	13.0	6.92	10.34	26.25
1951	38.0	17.2	10.28	14.48	36.76
1952	26.2	11.9	7.03	9.62	24.41
1953	11.6	5.3	1.56	2.12	5.39
1954	11.2	5.1	1.51	2.03	5.14
1955	37.7	17.1	6.08	8.06	20.47
1956	29.2	13.3	5.84	7.65	19.40
1957	27.8	12.6	5.03	6.37	16.16
1958	25.5	11.6	3.52	4.26	10.80
1959	19.6	8.9	4.04	4.80	12.17
1960	29.3	13.3	6.16	7.13	18.10
1961	22.7	10.3	4.34	4.90	12.44
1962	25.5	11.5	4.04	4.46	11.32
1963	21.7	9.8	3.88	4.19	10.63
1964	23.7	10.8	3.98	4.28	10.86
1965	18.8	8.5	3.92	4.14	10.51
1966	16.2	7.4	4.01	4.12	10.45
1967	12.4	5.6	2.42	2.42	6.14
1968	10.6	4.8	1.94	1.87	4.75
1969	13.8	6.3	2.56	2.36	6.00
1970	11.8	5.4	3.51	3.08	7.81
1971	2.3	1.1	0.80	0.67	1.70
1972	.	.	.	.	.
1973	0.5	0.2	.	.	.
1974	0.0	0.0	0.01	0.00	0.01
1975	.	.	.	.	.
1976	2.5	1.1	1.20	0.74	1.88
1977	41.2	18.7	67.93	39.54	100.35
1978	30.1	13.7	40.99	22.18	56.29
AVERAGE	20.0	9.1	7.83	6.76	17.16

Table 1-H.--Mahimahi. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	170.7	77.4	58.29	83.63	212.26
1950	276.1	125.2	81.70	122.13	309.96
1951	211.4	95.9	69.51	97.90	248.47
1952	187.1	84.9	70.04	95.82	243.19
1953	162.6	73.7	66.73	90.54	229.79
1954	235.8	106.9	77.23	103.81	263.47
1955	265.5	120.4	85.66	113.60	288.33
1956	183.6	83.2	68.43	89.57	227.33
1957	209.8	95.2	72.00	91.14	231.31
1958	149.0	67.6	57.83	69.85	177.28
1959	108.7	49.3	49.12	58.33	149.05
1960	90.6	41.1	50.17	58.13	147.53
1961	116.4	52.8	47.75	53.90	136.79
1962	109.0	49.4	46.63	51.46	130.61
1963	127.2	57.7	52.00	56.16	142.53
1964	85.4	38.7	46.56	50.12	127.20
1965	91.3	41.4	48.05	50.79	128.92
1966	85.4	38.7	41.36	42.51	107.83
1967	72.1	32.7	42.07	42.07	106.78
1968	73.5	33.4	49.29	47.49	120.53
1969	58.5	26.5	53.70	49.49	125.60
1970	76.1	34.5	54.82	48.00	121.83
1971	114.8	52.1	73.77	62.05	157.47
1972	175.2	79.5	115.01	93.65	237.69
1973	114.4	51.9	94.29	73.50	186.53
1974	111.4	50.5	108.27	76.30	193.64
1975	117.5	53.3	115.19	74.32	188.62
1976	139.1	63.1	178.40	109.58	278.12
1977	150.3	68.2	223.80	130.27	330.62
1978	130.8	59.3	217.45	117.67	298.64
AVERAGE	140.0	63.5	80.50	76.79	194.90

Table 1-I.--Ono (wahoo). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	49.0	22.2	15.98	22.93	58.19
1950	48.6	22.0	10.58	15.82	40.15
1951	38.8	17.6	10.48	14.75	37.45
1952	49.1	22.2	11.74	16.06	40.76
1953	50.8	23.0	11.17	15.15	38.46
1954	34.8	15.8	7.20	9.68	24.56
1955	38.8	17.6	8.13	10.79	27.37
1956	30.2	13.7	7.42	9.71	24.66
1957	31.3	14.2	7.23	9.15	23.22
1958	39.2	17.8	7.68	9.28	23.55
1959	30.1	13.7	6.40	7.60	19.28
1960	23.9	10.8	5.72	6.63	16.83
1961	25.4	11.5	5.07	5.72	14.53
1962	24.4	11.0	4.60	5.08	12.90
1963	29.8	13.5	5.47	5.91	15.00
1964	33.1	15.0	6.43	6.92	17.57
1965	31.0	14.1	6.09	6.43	16.33
1966	22.3	10.1	4.94	5.08	12.89
1967	39.2	17.8	8.60	8.60	21.82
1968	28.2	12.8	6.64	6.39	16.23
1969	35.2	15.9	9.27	8.54	21.68
1970	44.4	20.1	12.13	10.62	26.95
1971	39.2	17.8	12.02	10.11	25.67
1972	52.9	24.0	17.51	14.26	36.20
1973	75.7	34.4	30.91	24.09	61.15
1974	72.6	32.9	32.81	23.12	58.68
1975	114.4	51.9	67.05	43.26	109.79
1976	169.6	76.9	127.29	78.19	198.45
1977	223.4	101.3	203.81	118.64	301.10
1978	195.0	88.4	225.26	121.90	309.37
AVERAGE	57.3	26.0	29.85	21.68	55.03

Table 1-J.--Shark. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	28.8	13.1	4.61	6.90	17.51
1951	9.5	4.5	1.48	2.08	5.28
1952	15.8	7.2	2.83	3.87	9.82
1953	15.8	7.2	2.34	3.18	8.07
1954	0.2	0.1	0.02	0.02	0.05
1955	0.0	0.0	.	.	.
1956	.	.	.	.	.
1957	.	.	.	.	.
1958	.	.	.	.	.
1959	.	.	.	.	.
1960	.	.	.	.	.
1961	.	.	.	.	.
1962	.	.	.	.	.
1963	.	.	.	.	.
1964	.	.	.	.	.
1965	.	.	.	.	.
1966	.	.	.	.	.
1967	.	.	.	.	.
1968	.	.	.	.	.
1969	.	.	.	.	.
1970	.	.	.	.	.
1971	.	.	.	.	.
1972	.	.	.	.	.
1973	.	.	.	.	.
1974	.	.	.	.	.
1975	.	.	.	.	.
1976	.	.	.	.	.
1977	1.5	0.7	0.14	0.08	0.21
1978	22.2	10.1	1.50	0.81	2.06
AVERAGE	11.8	5.3	1.85	2.42	6.14

Table 1-K.--Tunas and billfishes. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	12157.8	5513.7	2382.53	3418.27	8675.57
1950	13227.9	5999.1	2403.51	3592.70	9118.26
1951	16875.0	7653.1	2914.07	4104.33	10416.78
1952	11378.2	5160.2	2337.41	3197.55	8115.37
1953	16564.5	7512.3	2752.07	3734.15	9477.27
1954	18421.3	8354.3	2763.24	3714.03	9426.21
1955	13141.9	5960.0	2137.78	2835.25	7195.88
1956	14534.8	6591.7	2245.60	2939.26	7459.85
1957	8873.7	4024.4	1709.86	2164.37	5493.18
1958	9622.0	4363.7	1812.98	2189.59	5557.19
1959	13507.2	6125.7	2199.41	2612.12	6629.57
1960	9609.0	4357.8	1906.40	2209.04	5606.55
1961	12948.7	5872.4	2135.67	2410.46	6117.75
1962	11574.9	5249.4	2056.14	2269.47	5759.91
1963	10062.0	4563.3	1917.01	2070.20	5254.17
1964	11123.4	5044.6	2096.18	2256.38	5726.70
1965	18040.5	8181.6	2835.48	2997.34	7607.24
1966	11208.9	5083.4	2273.41	2336.49	5930.01
1967	9844.2	4464.5	2180.32	2180.32	5533.64
1968	10896.6	4941.8	2481.85	2391.00	6065.35
1969	7650.3	3469.5	2443.93	2252.47	5716.78
1970	9154.1	4151.5	2813.19	2463.39	6252.08
1971	15032.8	6817.6	4003.21	3366.87	8545.11
1972	12531.0	5283.0	4327.07	3523.68	8943.09
1973	12223.2	5543.4	4661.49	3633.28	9221.25
1974	9380.2	4254.1	4535.64	3196.36	8112.36
1975	7592.7	3443.4	4548.54	2934.54	7447.87
1976	12650.8	5737.3	6561.93	4030.67	10229.84
1977	11047.9	5010.4	7253.43	4222.02	10715.49
1978	10890.4	4939.0	9077.34	4911.98	12466.61
AVERAGE	12058.9	5468.9	3192.22	3005.25	7627.33

Table 1-L.--Tunas. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	11137.2	5050.9	1985.19	2848.17	7229.69
1950	11941.3	5415.5	2079.46	3108.31	7888.39
1951	15736.4	7136.7	2571.32	3621.58	9191.57
1952	10420.5	4725.8	2027.54	2773.65	7039.53
1953	15581.3	7066.3	2525.33	3426.50	8696.44
1954	17358.3	7872.2	2579.06	3466.48	8797.93
1955	12354.7	5603.0	1953.06	2590.26	6574.09
1956	13781.4	6250.1	2075.84	2717.07	6895.91
1957	8245.0	3739.2	1541.21	1950.90	4951.38
1958	8897.1	4035.0	1648.86	1991.33	5054.13
1959	12828.8	5818.1	2017.98	2396.65	6082.71
1960	9024.3	4092.7	1738.56	2014.56	5112.94
1961	12407.0	5626.7	1987.17	2242.86	5692.37
1962	11063.0	5017.2	1921.55	2120.92	5382.89
1963	9507.7	4311.9	1757.76	1898.23	4817.70
1964	10406.0	4719.3	1908.99	2054.88	5215.29
1965	17450.5	7914.0	2665.71	2817.88	7151.78
1966	10696.5	4851.2	2111.98	2170.59	5508.96
1967	9264.0	4201.4	1983.30	1983.30	5033.62
1968	10349.7	4693.8	2255.47	2172.90	5514.82
1969	7162.1	3248.1	2177.46	2006.87	5093.45
1970	8570.9	3887.0	2521.35	2207.84	5603.49
1971	14722.4	6676.8	3856.04	3243.10	8230.98
1972	12301.8	5579.0	4212.48	3430.36	8706.25
1973	11992.3	5438.7	4552.60	3548.40	9005.85
1974	9057.1	4107.5	4413.75	3110.47	7894.37
1975	7245.5	3285.9	4400.22	2838.85	7205.00
1976	12232.1	5547.5	6386.25	3922.76	9955.95
1977	10527.1	4774.2	6968.91	4056.41	10295.17
1978	10149.6	4603.0	8635.39	4672.83	11859.65
AVERAGE	11413.7	5176.3	2981.99	2780.16	7056.06

Table 1-M.--Aku (skipjack tuna). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	9066.3	4111.7	1254.64	1800.06	4568.55
1950	9310.3	4222.3	1316.50	1967.86	4994.42
1951	12877.1	5840.0	1727.80	2433.53	6176.29
1952	7229.1	3278.5	1052.23	1439.44	3653.29
1953	12059.4	5469.1	1593.74	2162.47	5488.36
1954	14021.5	6358.9	1760.97	2366.90	6007.19
1955	9694.5	4396.6	1114.63	1478.29	3751.89
1956	11132.2	5048.6	1261.78	1651.55	4191.64
1957	6130.2	2780.1	794.13	1005.23	2551.28
1958	6834.5	3099.6	899.41	1086.24	2756.89
1959	11104.1	5035.9	1321.34	1569.29	3982.86
1960	7359.9	3337.8	1001.02	1159.93	2943.89
1961	10894.3	4940.7	1306.74	1474.87	3743.23
1962	9415.4	4270.0	1173.99	1295.79	3288.72
1963	8099.3	3673.2	1089.82	1176.91	2987.00
1964	9023.6	4092.3	1221.70	1315.07	3337.65
1965	16157.3	7327.6	2013.86	2128.82	5402.94
1966	9384.5	4256.0	1403.62	1442.57	3661.25
1967	8039.7	3646.1	1263.12	1263.12	3205.79
1968	9319.7	4226.6	1539.62	1483.25	3764.50
1969	5963.3	2704.4	1245.20	1147.65	2912.74
1970	7351.1	3333.8	1496.52	1310.79	3326.78
1971	13340.8	6050.3	2752.71	2315.15	5875.84
1972	10917.4	4951.2	2949.37	2401.77	6095.69
1973	10751.1	4875.8	3203.25	2496.68	6336.58
1974	7436.2	3372.4	2676.04	1885.86	4786.32
1975	5054.0	2292.1	2282.17	1472.37	3736.86
1976	9796.2	4442.7	3826.87	2350.66	5565.97
1977	7750.3	3514.9	3707.38	2157.97	5476.92
1978	6794.1	3081.2	4358.43	2358.46	5985.77
AVERAGE	9410.3	4267.7	1820.30	1719.95	4365.24

Table 1-N.--Ahi (yellowfin tuna, bigeye tuna, and miscellaneous). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	2013.1	913.0	715.10	1025.97	2603.90
1950	2539.4	1151.6	745.04	1113.67	2326.49
1951	2788.8	1264.2	826.02	1163.41	2952.73
1952	3035.5	1376.7	940.42	1286.49	3265.10
1953	3447.8	1563.6	918.21	1245.88	3162.03
1954	3285.0	1489.8	809.24	1087.69	2760.56
1955	2599.3	1178.8	827.13	1096.99	2734.17
1956	2574.9	1167.7	800.06	1047.20	2657.80
1957	2015.9	914.2	730.89	925.18	2748.11
1958	2004.3	909.0	739.38	892.97	2267.36
1959	1699.4	770.7	691.37	821.10	2083.95
1960	1651.3	748.9	734.04	850.56	2158.73
1961	1497.0	678.9	675.98	762.96	1936.39
1962	1617.6	733.6	741.10	817.99	2076.07
1963	1333.1	604.6	654.91	707.25	1795.00
1964	1338.4	607.0	678.34	730.19	1853.22
1965	1271.5	576.6	648.37	695.38	1739.49
1966	1265.3	573.8	698.06	717.44	1820.85
1967	1148.8	521.0	705.87	705.87	1791.49
1968	978.2	443.6	702.74	677.01	1718.26
1969	1132.5	513.6	909.82	838.55	2128.23
1970	1182.1	536.1	1008.99	893.53	2242.41
1971	1329.6	603.0	1085.21	912.71	2316.46
1972	1329.9	603.1	1244.20	1013.19	2571.43
1973	1177.9	534.2	1313.83	1024.03	2598.99
1974	1566.7	710.5	1713.88	1207.81	3065.41
1975	2052.1	930.7	2036.51	1313.88	3334.62
1976	2284.4	1036.0	2495.85	1533.08	3890.95
1977	2600.7	1179.5	3159.66	1839.15	4667.76
1978	2582.6	1171.2	3745.36	2026.71	5143.79
AVERAGE	1911.4	866.9	1123.19	1031.79	2618.69

Table 1-0.--Ahi (bigeye tuna). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	1821.2	826.0	546.04	816.20	2071.51
1951	2034.0	922.4	600.94	846.40	2148.15
1952	2188.6	992.6	682.55	933.72	2369.78
1953	2826.2	1281.7	761.25	1032.91	2621.51
1954	2759.2	1251.3	672.15	903.43	2292.92
1955	2153.6	976.7	687.28	911.51	2313.42
1956	2270.9	1029.9	713.54	933.96	2370.38
1957	1632.9	740.6	619.93	784.72	1991.63
1958	1596.4	724.0	622.26	751.52	1907.36
1959	1214.7	550.9	537.50	638.36	1620.16
1960	1295.6	587.6	581.54	673.86	1710.26
1961	1037.4	470.5	507.56	572.87	1453.94
1962	1220.8	553.6	598.07	660.13	1675.40
1963	948.3	430.0	501.73	541.82	1375.14
1964	838.3	380.2	492.86	530.53	1346.47
1965	773.9	351.0	471.07	497.96	1263.82
1966	762.6	345.8	483.15	496.56	1260.26
1967	647.1	293.5	475.52	475.52	1206.86
1968	563.9	255.7	498.56	480.31	1219.03
1969	709.8	321.9	673.46	620.70	1575.34
1970	476.8	216.3	510.01	446.60	1133.47
1971	472.6	214.3	568.13	477.82	1212.70
1972	504.0	228.6	683.84	556.88	1413.35
1973	408.5	185.3	688.35	536.51	1361.67
1974	412.9	187.3	730.82	515.02	1307.13
1975	346.3	157.0	673.03	434.22	1102.04
1976	433.0	196.4	823.33	505.73	1283.55
1977	546.0	247.6	1121.80	652.97	1657.23
1978	460.4	208.8	1273.51	689.13	1749.01
AVERAGE	1150.2	521.6	648.27	652.34	1655.64

Table 1-P.--Ahi (yellowfin tuna). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	2013.1	913.0	715.10	1025.97	2603.90
1950	712.7	323.2	197.34	294.99	748.67
1951	754.8	342.3	225.08	317.01	204.58
1952	846.9	384.1	257.87	352.77	895.32
1953	621.7	281.9	156.96	212.97	540.52
1954	525.8	238.4	137.09	184.26	467.64
1955	445.8	202.2	139.85	185.48	470.75
1956	304.0	137.9	86.52	113.25	237.42
1957	383.0	173.7	110.96	140.46	356.48
1958	407.9	185.0	117.12	141.45	359.00
1959	484.7	219.8	153.87	182.74	462.79
1960	355.6	161.3	152.49	176.70	448.47
1961	459.6	208.5	168.42	190.09	442.44
1962	396.8	179.9	143.03	157.87	400.67
1963	384.9	174.5	153.19	165.43	419.86
1964	500.1	226.8	185.49	199.66	506.74
1965	497.6	225.7	177.30	187.42	475.67
1966	502.7	228.0	214.91	220.88	560.59
1967	501.7	227.6	230.35	230.35	534.62
1968	414.3	187.9	204.18	196.70	499.23
1969	422.7	191.7	236.36	217.84	552.89
1970	705.3	319.9	498.98	436.94	1109.94
1971	857.0	388.7	517.09	434.89	1103.76
1972	825.9	374.5	560.36	456.32	1158.13
1973	769.4	348.9	625.49	487.52	1237.32
1974	1153.8	523.2	983.06	692.78	1758.29
1975	1705.9	773.6	1363.47	879.66	2232.53
1976	1851.4	839.7	1672.52	1027.34	2607.40
1977	2054.7	931.8	2037.86	1186.13	3010.53
1978	2122.2	962.5	2471.85	1337.59	3394.73
AVERAGE	799.4	362.5	496.47	401.12	1018.03

Table 1-Q.--Ahipalaha (albacore). Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	60.9	27.6	11.75	17.57	44.58
1951	56.0	25.4	14.10	19.86	50.41
1952	104.3	47.3	23.73	32.46	82.38
1953	49.4	22.4	8.55	11.60	29.45
1954	28.7	13.0	4.79	6.44	16.34
1955	20.7	9.4	4.22	5.59	14.19
1956	13.4	6.1	3.67	4.81	12.20
1957	9.6	4.4	2.64	3.35	8.49
1958	16.2	7.4	3.54	4.28	10.85
1959	9.5	4.3	2.10	2.50	6.34
1960	8.9	4.0	2.60	3.01	7.63
1961	13.6	6.1	4.08	4.60	11.69
1962	16.7	7.6	4.03	4.45	11.29
1963	15.0	6.8	4.68	5.05	12.82
1964	9.5	4.3	3.11	3.34	8.49
1965	6.7	3.1	1.75	1.85	4.70
1966	19.1	8.7	6.38	6.55	16.64
1967	26.5	12.0	8.94	8.04	22.69
1968	22.6	10.3	8.21	7.91	20.08
1969	27.4	12.4	12.36	11.39	28.92
1970	20.0	9.1	10.64	9.32	23.64
1971	23.4	10.6	11.08	9.32	23.64
1972	18.0	8.2	11.74	9.56	24.26
1973	30.7	13.9	27.64	21.54	54.68
1974	19.5	8.8	14.89	10.49	26.63
1975	73.6	33.4	65.56	42.30	107.35
1976	60.1	27.3	40.31	24.76	62.85
1977	79.4	36.0	72.90	42.43	107.69
1978	694.4	314.9	493.31	266.94	677.50
AVERAGE	53.6	24.3	30.46	20.77	52.70

Table 1-R.--Kawakawa. Annual figures from 1949 to 1978.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	57.8	26.2	15.44	22.15	56.21
1950	30.7	13.9	6.16	9.22	23.39
1951	14.4	6.5	3.39	4.78	12.14
1952	51.5	23.4	11.16	15.27	39.76
1953	24.6	11.2	4.82	6.54	16.60
1954	23.2	10.5	4.06	5.45	13.84
1955	40.1	18.2	7.08	9.39	23.83
1956	60.9	27.6	10.32	13.50	34.27
1957	89.2	40.5	13.54	17.14	43.50
1958	42.0	19.1	6.53	7.89	20.03
1959	15.8	7.2	3.17	3.76	9.55
1960	4.2	1.9	0.91	1.06	2.68
1961	2.1	0.9	0.37	0.42	1.07
1962	13.3	6.0	2.43	2.69	6.82
1963	60.2	27.3	8.35	9.02	22.88
1964	34.5	15.7	5.83	6.28	15.94
1965	14.9	6.8	1.73	1.83	4.65
1966	27.9	12.7	3.92	4.03	10.22
1967	49.1	22.3	5.38	5.38	13.65
1968	29.2	13.2	4.90	4.72	11.98
1969	38.9	17.6	10.07	9.28	23.55
1970	17.6	8.0	4.80	4.20	10.66
1971	28.6	13.0	7.04	5.92	15.03
1972	36.6	16.6	7.17	5.84	14.82
1973	32.5	14.7	7.88	6.14	15.59
1974	34.8	15.8	8.95	6.31	16.01
1975	65.8	29.8	15.98	10.31	26.17
1976	91.4	41.4	23.22	14.26	36.19
1977	96.7	43.9	28.97	16.86	42.80
1978	78.5	35.6	38.29	20.72	52.59
AVERAGE	40.2	18.2	9.06	8.35	21.18

Table 2-A.--Billfishes. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	26.6	12.1	10.34	10.95	27.80
FEBRUARY	44.4	20.2	16.04	17.50	44.42
MARCH	46.7	21.2	20.19	22.16	56.25
APRIL	49.6	22.5	18.55	19.92	50.56
MAY	65.2	29.6	19.00	19.64	49.85
JUNE	63.8	29.0	16.38	16.78	42.60
JULY	59.8	27.1	15.04	16.43	41.71
AUGUST	64.2	29.1	17.15	19.72	50.05
SEPTEMBER	52.0	23.6	14.87	16.99	43.12
OCTOBER	55.2	25.1	17.06	18.61	47.24
NOVEMBER	58.1	26.4	19.09	19.73	50.08
DECEMBER	59.4	26.9	26.52	26.64	67.61
AVERAGE	53.8	24.4	17.52	18.76	47.61

Table 2-B.--Black marlin. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	0.8	0.4	0.29	0.32	0.81
FEBRUARY	0.7	0.3	0.24	0.29	0.72
MARCH	0.9	0.4	0.32	0.36	0.93
APRIL	0.9	0.4	0.27	0.29	0.73
MAY	1.9	0.9	0.43	0.50	1.27
JUNE	1.0	0.5	0.22	0.26	0.65
JULY	1.1	0.5	0.27	0.31	0.79
AUGUST	1.1	0.5	0.30	0.34	0.87
SEPTEMBER	1.0	0.5	0.24	0.29	0.74
OCTOBER	1.1	0.5	0.25	0.28	0.71
NOVEMBER	1.2	0.5	0.34	0.38	0.96
DECEMBER	0.8	0.4	0.29	0.31	0.79
AVERAGE	1.0	0.5	0.29	0.32	0.82

Table 2-C.--Blue marlin. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	8.0	3.6	2.40	2.51	6.37
FEBRUARY	10.7	4.8	3.30	3.61	9.17
MARCH	12.5	5.7	4.66	5.29	13.41
APRIL	16.0	7.2	4.81	5.47	13.89
MAY	21.5	9.7	5.36	5.99	15.21
JUNE	26.6	12.1	6.00	6.30	15.99
JULY	40.7	18.5	9.68	10.71	27.18
AUGUST	50.8	23.0	13.53	15.69	39.79
SEPTEMBER	40.6	18.4	11.11	12.77	32.41
OCTOBER	32.3	14.7	8.38	9.65	24.48
NOVEMBER	23.1	10.5	6.96	7.63	19.50
DECEMBER	15.4	7.0	5.74	6.20	15.73
AVERAGE	24.9	11.3	6.80	7.63	19.36

Table 2-D.--Sailfish. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	2.8	1.3	1.16	1.64	4.15
FEBRUARY	7.5	3.4	2.26	3.21	8.16
MARCH	6.3	2.9	2.40	3.37	8.55
APRIL	6.5	2.9	2.30	3.23	8.19
MAY	6.4	2.9	1.61	2.29	5.79
JUNE	1.5	0.7	1.08	1.53	3.89
JULY	4.0	1.8	1.33	1.88	4.77
AUGUST	5.4	2.5	1.91	2.72	6.91
SEPTEMBER	3.9	1.8	1.52	2.15	5.46
OCTOBER	4.8	2.2	1.78	2.50	6.35
NOVEMBER	3.8	1.7	1.12	1.57	3.99
DECEMBER	4.2	1.9	1.15	1.61	4.09
AVERAGE	4.7	2.1	1.63	2.30	5.82

Table 2-E.--Shortbill spearfish. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	1.4	0.6	0.71	0.40	1.00
FEBRUARY	2.1	1.0	1.52	0.84	2.14
MARCH	1.4	0.6	1.14	0.64	1.62
APRIL	2.1	1.0	1.65	0.97	2.46
MAY	2.1	1.0	1.08	0.62	1.59
JUNE	1.5	0.7	0.61	0.36	0.91
JULY	1.0	0.5	0.33	0.19	0.47
AUGUST	0.7	0.3	0.21	0.12	0.31
SEPTEMBER	0.5	0.2	0.18	0.11	0.27
OCTOBER	0.5	0.2	0.37	0.21	0.54
NOVEMBER	0.8	0.4	0.61	0.35	0.88
DECEMBER	1.6	0.7	1.48	0.84	2.14
AVERAGE	1.3	0.6	0.81	0.46	1.17

Table 2-F.--Striped marlin. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	15.7	7.1	6.97	7.07	17.95
FEBRUARY	27.6	12.5	10.88	11.25	28.54
MARCH	28.9	13.1	13.64	14.21	36.03
APRIL	26.6	12.1	11.40	11.35	28.81
MAY	33.3	15.1	10.12	10.12	25.68
JUNE	31.6	14.3	7.63	7.52	19.84
JULY	14.0	6.3	3.70	3.78	9.58
AUGUST	8.9	4.1	2.50	2.35	5.97
SEPTEMBER	7.9	3.6	2.83	2.76	7.02
OCTOBER	18.6	8.4	7.20	6.83	17.35
NOVEMBER	31.9	14.5	11.74	11.30	28.68
DECEMBER	40.8	18.5	20.25	19.52	49.54
AVERAGE	23.8	10.8	9.07	9.03	22.92

Table 2-G.--Swordfish (broadbill). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	0.4	0.2	0.18	0.21	0.52
FEBRUARY	0.5	0.2	0.16	0.22	0.55
MARCH	0.7	0.3	0.20	0.24	0.60
APRIL	2.1	0.9	0.62	0.67	1.69
MAY	6.9	3.1	2.93	2.32	5.88
JUNE	7.1	3.2	2.73	2.10	5.32
JULY	2.6	1.2	1.12	0.91	2.30
AUGUST	0.8	0.4	0.22	0.22	0.56
SEPTEMBER	0.7	0.3	0.22	0.26	0.67
OCTOBER	0.4	0.2	0.13	0.13	0.34
NOVEMBER	0.5	0.4	0.26	0.32	0.81
DECEMBER	0.4	0.2	0.14	0.16	0.41
AVERAGE	2.0	0.5	0.78	0.67	1.71

Table 2-H.--Mahimahi. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	3.5	1.6	3.07	2.66	6.76
FEBRUARY	6.3	2.8	4.58	4.37	11.09
MARCH	11.9	5.4	7.64	7.47	19.97
APRIL	20.4	9.2	10.51	10.00	25.39
MAY	19.9	9.0	8.78	8.70	22.08
JUNE	12.4	5.6	5.53	5.56	14.11
JULY	11.1	5.0	5.85	5.82	14.77
AUGUST	9.9	4.5	6.07	5.90	14.96
SEPTEMBER	10.6	4.8	6.87	6.39	16.21
OCTOBER	14.3	6.5	9.08	8.27	20.99
NOVEMBER	12.6	5.7	7.49	6.97	17.68
DECEMBER	7.1	3.2	5.03	4.68	11.88
AVERAGE	11.7	5.3	6.71	6.40	16.24

Table 2-I.--Ono (wahoo). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	1.6	0.7	0.81	0.64	1.61
FEBRUARY	1.7	0.8	0.90	0.71	1.79
MARCH	2.4	1.1	1.55	1.14	2.88
APRIL	4.5	2.0	2.63	1.87	4.75
MAY	6.7	3.0	3.52	2.43	6.17
JUNE	7.6	3.5	3.53	2.52	6.40
JULY	8.8	4.0	3.99	2.89	7.34
AUGUST	7.5	3.4	3.71	2.73	6.94
SEPTEMBER	6.1	2.8	2.89	2.26	5.73
OCTOBER	4.4	2.0	2.54	1.82	4.61
NOVEMBER	2.8	1.3	1.85	1.29	3.27
DECEMBER	3.2	1.4	1.93	1.39	3.52
AVERAGE	4.8	2.2	2.49	1.81	4.59

Table 2-J.--Shark. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	1.7	0.8	0.27	0.36	0.92
FEBRUARY	0.8	0.4	0.13	0.15	0.39
MARCH	0.6	0.3	0.05	0.05	0.13
APRIL	1.1	0.5	0.08	0.07	0.18
MAY	2.0	0.9	0.23	0.18	0.46
JUNE	1.9	0.9	0.26	0.35	0.89
JULY	2.0	0.9	0.71	0.44	1.12
AUGUST	2.2	1.0	0.34	0.50	1.23
SEPTEMBER	2.7	1.2	0.39	0.55	1.41
OCTOBER	1.9	0.9	0.25	0.34	0.87
NOVEMBER	0.9	0.4	0.12	0.15	0.39
DECEMBER	1.3	0.6	0.21	0.29	0.73
AVERAGE	1.6	0.7	0.22	0.29	0.73

Table 2-K.--Tunas and billfishes. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	455.2	206.4	171.01	151.30	383.99
FEBRUARY	421.6	191.2	174.06	159.84	405.68
MARCH	467.7	212.1	178.32	172.93	438.90
APRIL	712.1	323.0	217.04	206.37	523.76
MAY	1308.6	593.5	307.32	289.44	734.61
JUNE	1823.1	826.8	365.74	348.95	885.64
JULY	2027.3	919.4	393.62	381.73	968.83
AUGUST	1705.7	773.6	350.03	341.31	866.25
SEPTEMBER	1085.7	492.4	255.00	244.41	620.32
OCTOBER	836.0	379.1	239.32	225.33	571.89
NOVEMBER	608.1	275.8	225.20	202.72	514.50
DECEMBER	607.7	275.6	315.57	280.91	712.95
AVERAGE	1004.9	455.7	266.02	250.44	635.61

Table 2-L.--Tunas. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	428.6	194.4	160.67	140.35	356.20
FEBRUARY	377.2	171.1	158.02	142.34	361.27
MARCH	421.0	190.9	153.13	150.77	382.66
APRIL	662.6	300.5	198.49	186.45	473.20
MAY	1243.4	563.9	288.32	259.90	694.76
JUNE	1759.2	797.8	349.36	332.17	843.05
JULY	1967.5	892.3	378.58	365.30	927.12
AUGUST	1641.5	744.5	332.88	321.59	816.21
SEPTEMBER	1033.7	468.8	240.13	227.42	577.20
OCTOBER	780.7	354.1	222.26	206.72	524.64
NOVEMBER	550.0	249.4	206.12	182.99	464.42
DECEMBER	548.4	248.7	299.05	254.27	645.34
AVERAGE	951.1	431.4	248.50	231.68	588.00

Table 2-M.--Aku (skipjack tuna). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	314.4	142.6	88.04	74.30	138.56
FEBRUARY	218.9	99.3	66.72	57.72	146.48
MARCH	283.0	128.3	77.49	71.48	131.42
APRIL	500.6	227.0	119.33	109.83	278.75
MAY	1076.8	488.4	197.05	187.07	474.77
JUNE	1585.3	719.0	264.89	256.34	650.60
JULY	1792.3	812.8	291.22	297.50	729.69
AUGUST	1491.8	676.6	247.32	245.82	623.83
SEPTEMBER	878.3	398.3	153.74	149.97	380.63
OCTOBER	603.3	273.6	120.36	114.55	290.74
NOVEMBER	374.8	170.0	95.43	83.59	212.15
DECEMBER	290.7	131.8	98.72	81.78	207.57
AVERAGE	784.2	355.6	151.69	143.33	363.77

Table 2-N.--Ahi (yellowfin tuna, bigeye tuna, and miscellaneous). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TUNS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	110.3	50.0	71.38	65.02	165.01
FEBRUARY	153.9	69.8	90.00	83.50	211.93
MARCH	132.8	60.2	79.04	77.80	197.44
APRIL	157.5	71.4	77.93	75.41	191.39
MAY	162.9	73.9	89.95	81.67	207.28
JUNE	168.1	76.2	82.67	74.30	188.56
JULY	163.3	74.1	82.29	74.35	188.70
AUGUST	137.4	62.3	80.10	72.08	182.95
SEPTEMBER	139.6	63.3	78.94	72.58	184.21
OCTOBER	168.1	76.3	97.61	89.04	225.99
NOVEMBER	168.4	76.4	107.37	97.00	246.19
DECEMBER	249.1	113.0	185.91	169.04	429.03
AVERAGE	159.3	72.2	93.60	85.98	218.22

Table 2-0.--Ahi (bigeye tuna). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	71.1	32.3	42.16	43.05	109.27
FEBRUARY	103.8	47.1	57.30	57.92	147.00
MARCH	100.6	45.6	57.76	60.00	152.28
APRIL	117.1	53.1	54.51	56.39	143.13
MAY	103.1	46.8	54.22	53.68	136.24
JUNE	63.7	28.9	28.52	29.79	75.61
JULY	45.8	20.8	21.25	22.90	58.12
AUGUST	45.5	20.6	26.22	27.45	69.66
SEPTEMBER	73.8	33.5	40.25	41.74	105.93
OCTOBER	116.2	52.7	64.56	63.31	160.69
NOVEMBER	124.4	56.4	72.97	71.16	180.60
DECEMBER	187.5	85.0	129.14	125.97	319.70
AVERAGE	96.1	43.6	54.18	54.52	138.37

Table 2-P.--Ahi (yellowfin tuna). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	41.5	18.8	30.62	23.40	59.38
FEBRUARY	53.5	24.3	34.61	27.51	69.83
MARCH	35.6	16.1	23.21	19.79	50.24
APRIL	44.2	20.0	25.18	20.81	52.82
MAY	63.2	28.7	37.54	29.78	75.59
JUNE	108.6	49.3	55.68	46.49	117.99
JULY	119.0	54.0	61.74	52.21	132.52
AUGUST	93.5	42.4	54.75	45.55	115.60
SEPTEMBER	68.3	31.0	40.04	32.23	81.81
OCTOBER	55.8	25.3	35.20	27.84	70.66
NOVEMBER	48.1	21.8	36.83	28.21	71.61
DECEMBER	67.9	30.8	61.07	47.27	119.98
AVERAGE	66.6	30.2	41.37	33.43	84.84

Table 2-Q.--Ahipalaha (albacore). Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	1.3	0.6	0.89	0.58	1.47
FEBRUARY	0.8	0.4	0.55	0.38	0.95
MARCH	0.4	0.2	0.28	0.24	0.61
APRIL	1.0	0.5	0.42	0.44	1.12
MAY	1.7	0.8	1.01	0.75	1.90
JUNE	4.5	2.0	1.57	1.31	3.32
JULY	9.8	4.5	4.84	3.14	7.98
AUGUST	9.9	4.5	5.17	3.36	8.53
SEPTEMBER	13.1	5.9	7.01	4.40	11.16
OCTOBER	5.4	2.5	3.54	2.51	6.37
NOVEMBER	3.0	1.4	2.59	1.73	4.38
DECEMBER	4.2	1.9	3.48	2.62	6.64
AVERAGE	5.1	2.3	2.91	1.98	5.03

Table 2-R.--Kawakawa. Monthly figures from 1949 to 1978.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	3.1	1.4	0.69	0.67	1.09
FEBRUARY	3.9	1.8	0.94	0.89	2.26
MARCH	5.1	2.3	1.49	1.40	3.55
APRIL	3.9	1.7	0.97	0.94	2.39
MAY	2.2	1.0	0.44	0.41	1.05
JUNE	1.7	0.8	0.33	0.31	0.78
JULY	2.4	1.1	0.41	0.40	1.03
AUGUST	2.7	1.2	0.47	0.45	1.13
SEPTEMBER	3.0	1.4	0.67	0.62	1.59
OCTOBER	4.0	1.8	0.87	0.85	1.76
NOVEMBER	3.9	1.8	0.81	0.73	1.84
DECEMBER	4.5	2.0	1.06	0.92	2.33
AVERAGE	3.4	1.5	0.76	0.70	1.77

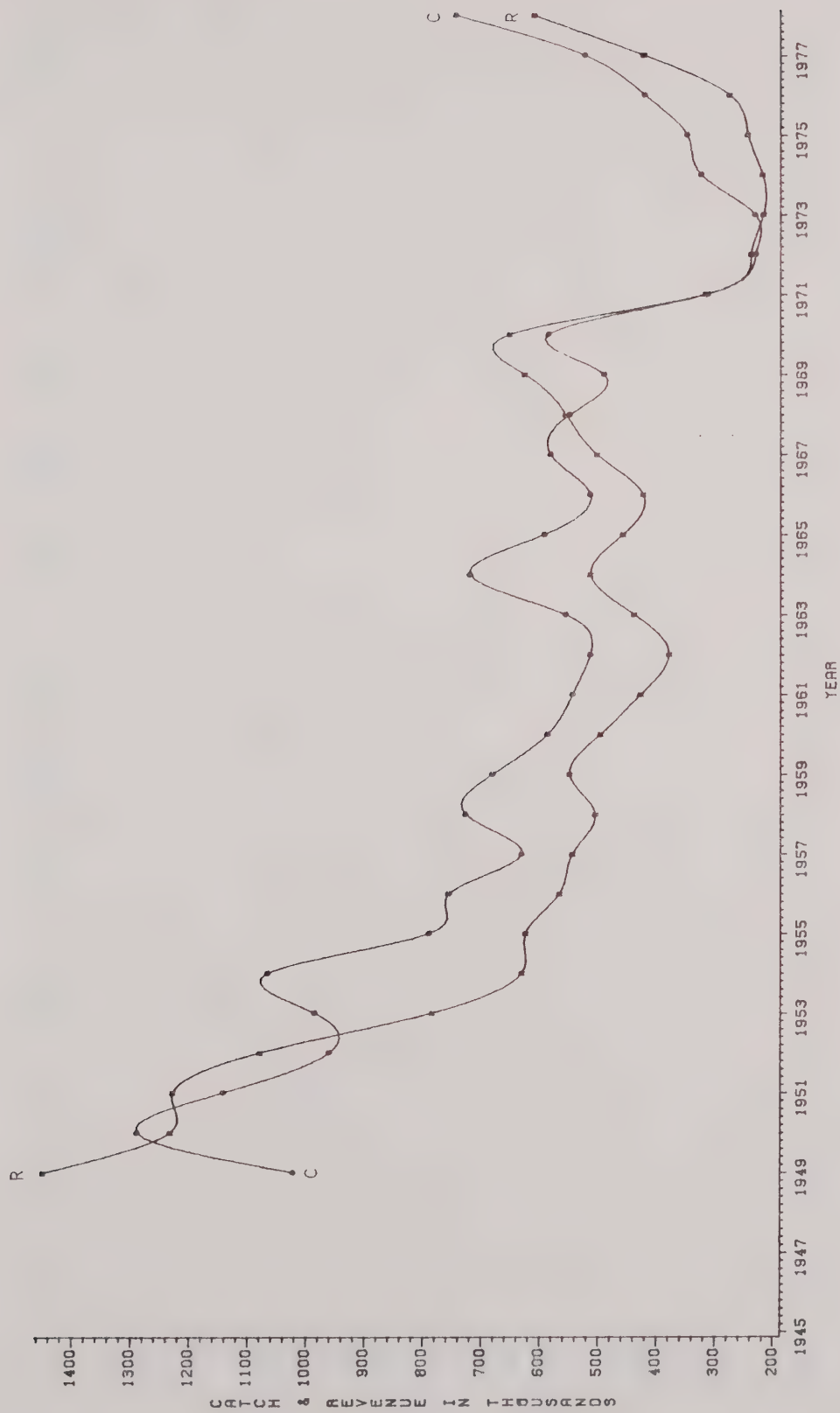


Figure 1-A.--Billfishes. Plot of revenue in 1981 dollars and catch by year.

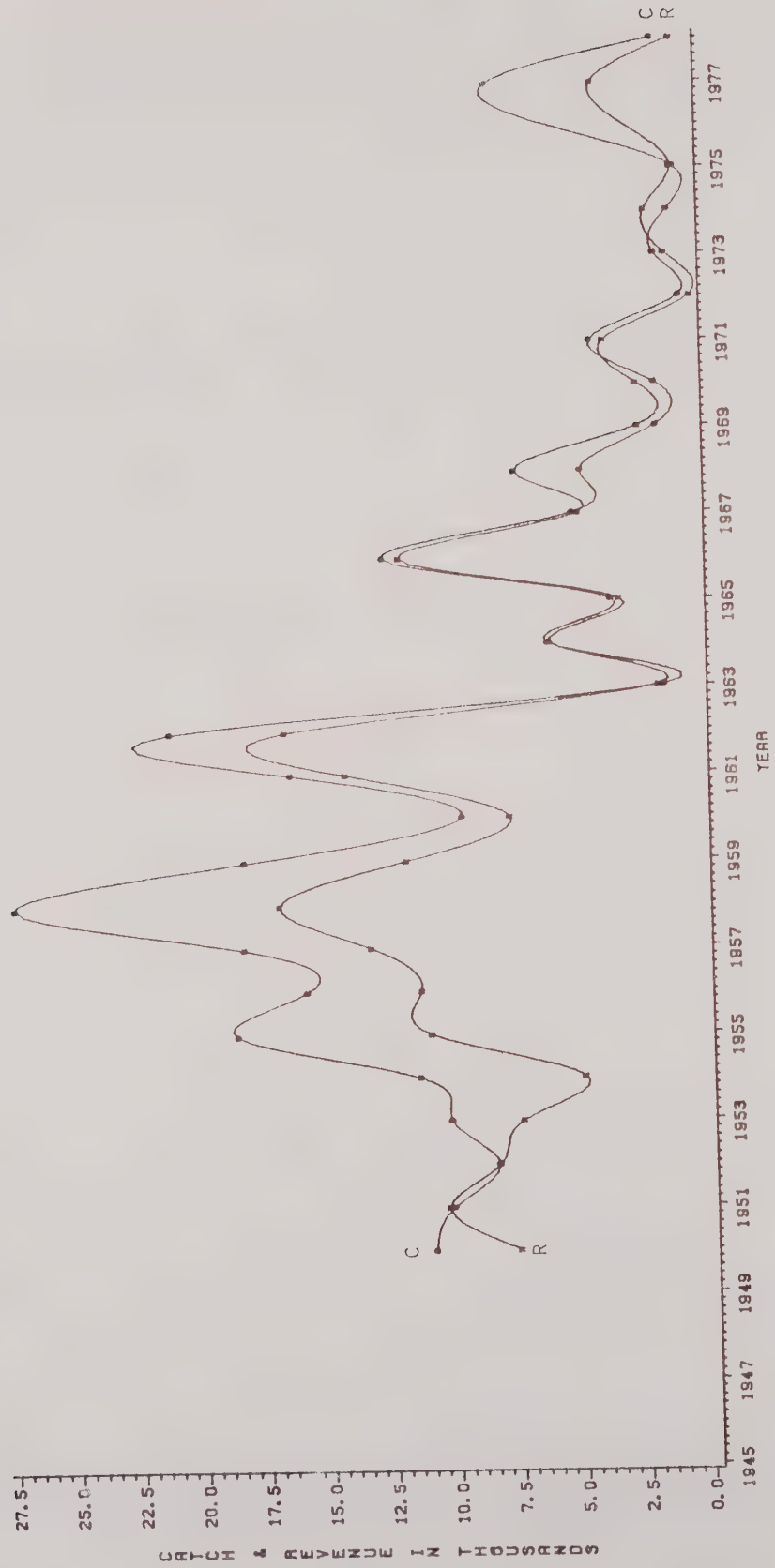


Figure 1-B.--Black marlin. Plot of revenue in 1981 dollars and catch by year.

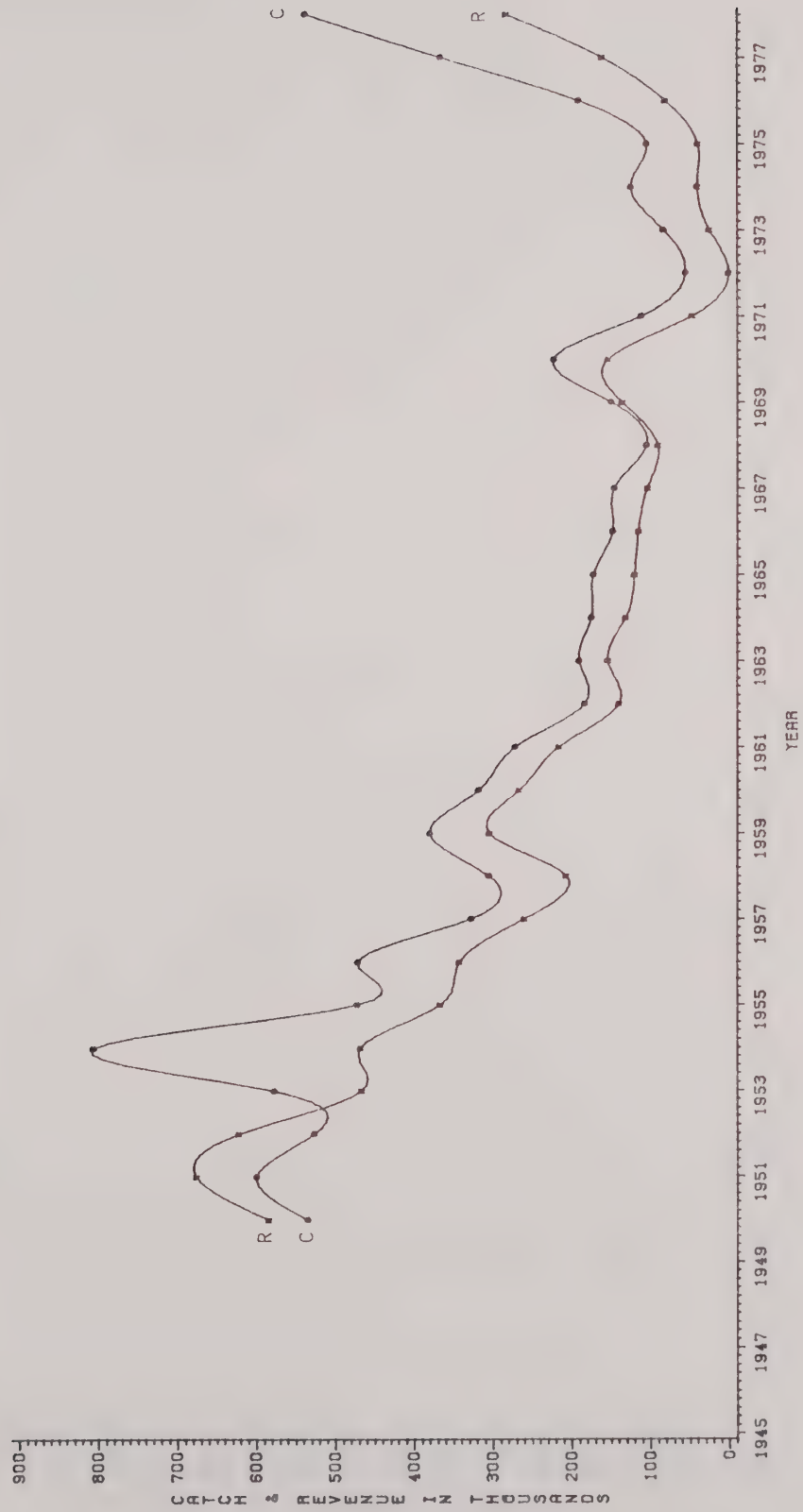


Figure 1-C.--Blue marlin. Plot of revenue in 1981 dollars and catch by year.

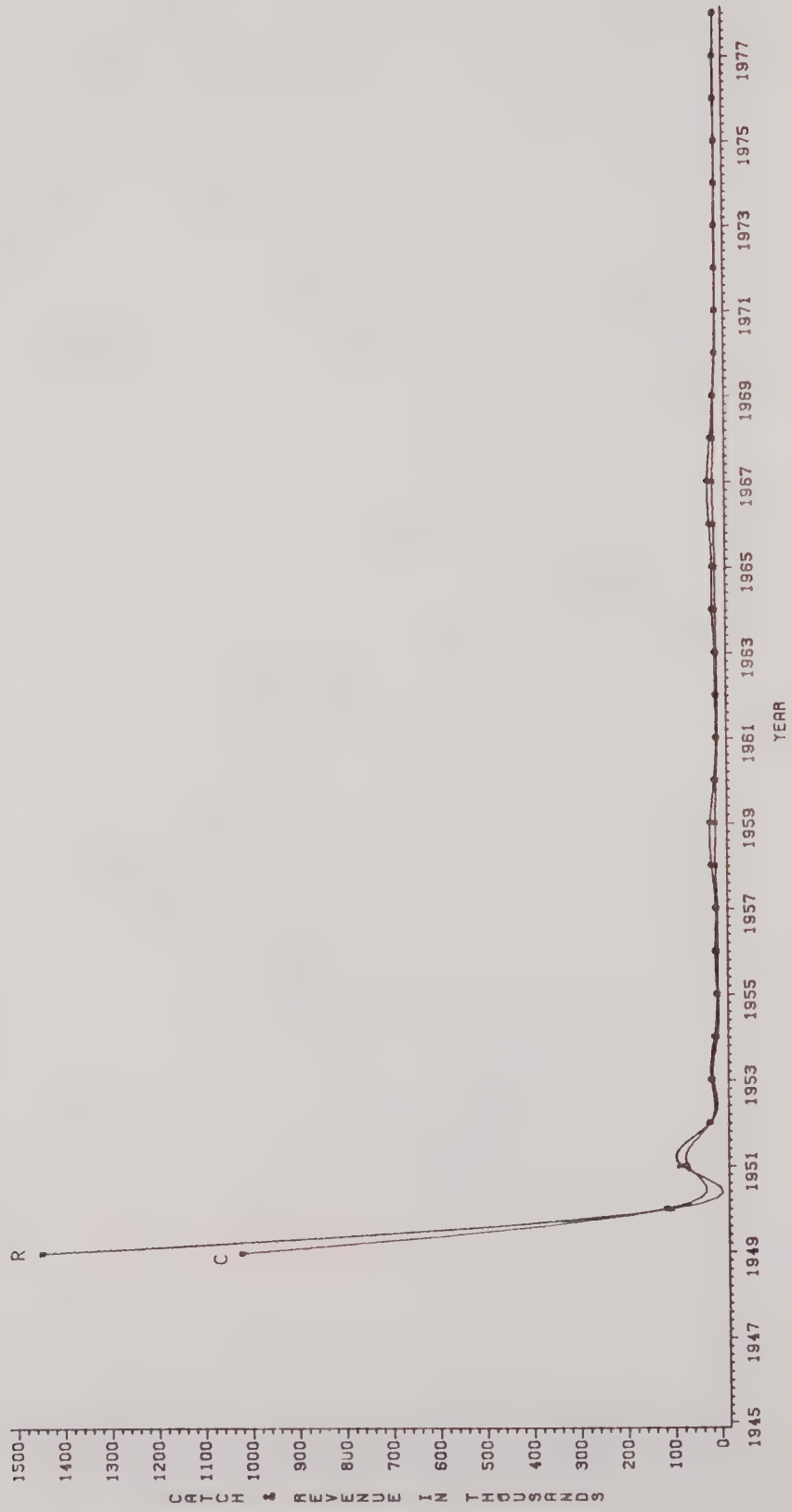


Figure 1-D.--Sailfish. Plot of revenue in 1981 dollars and catch by year.

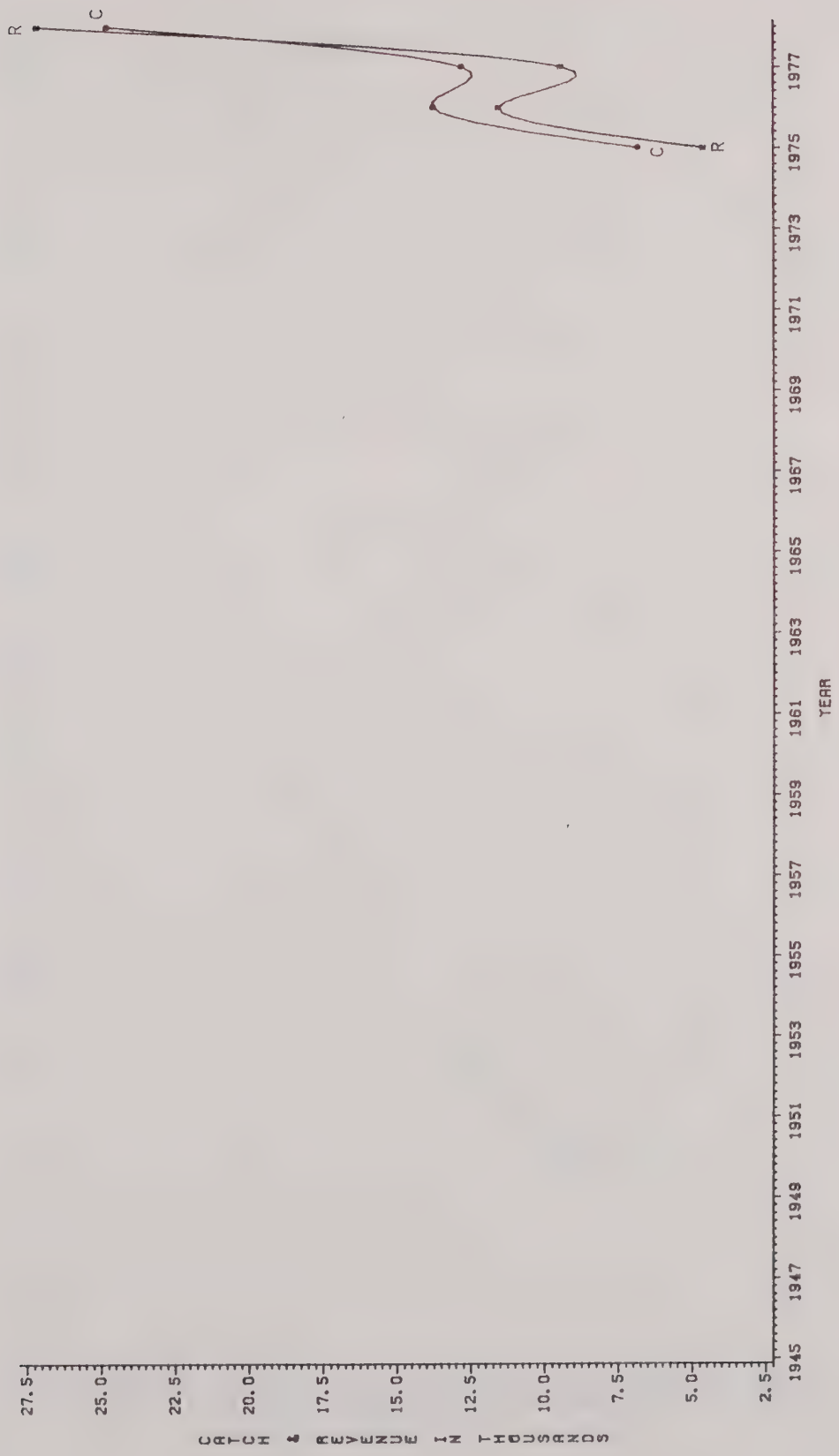


Figure 1-E.--Shortbill spearfish. Plot of revenue in 1981 dollars and catch by year.

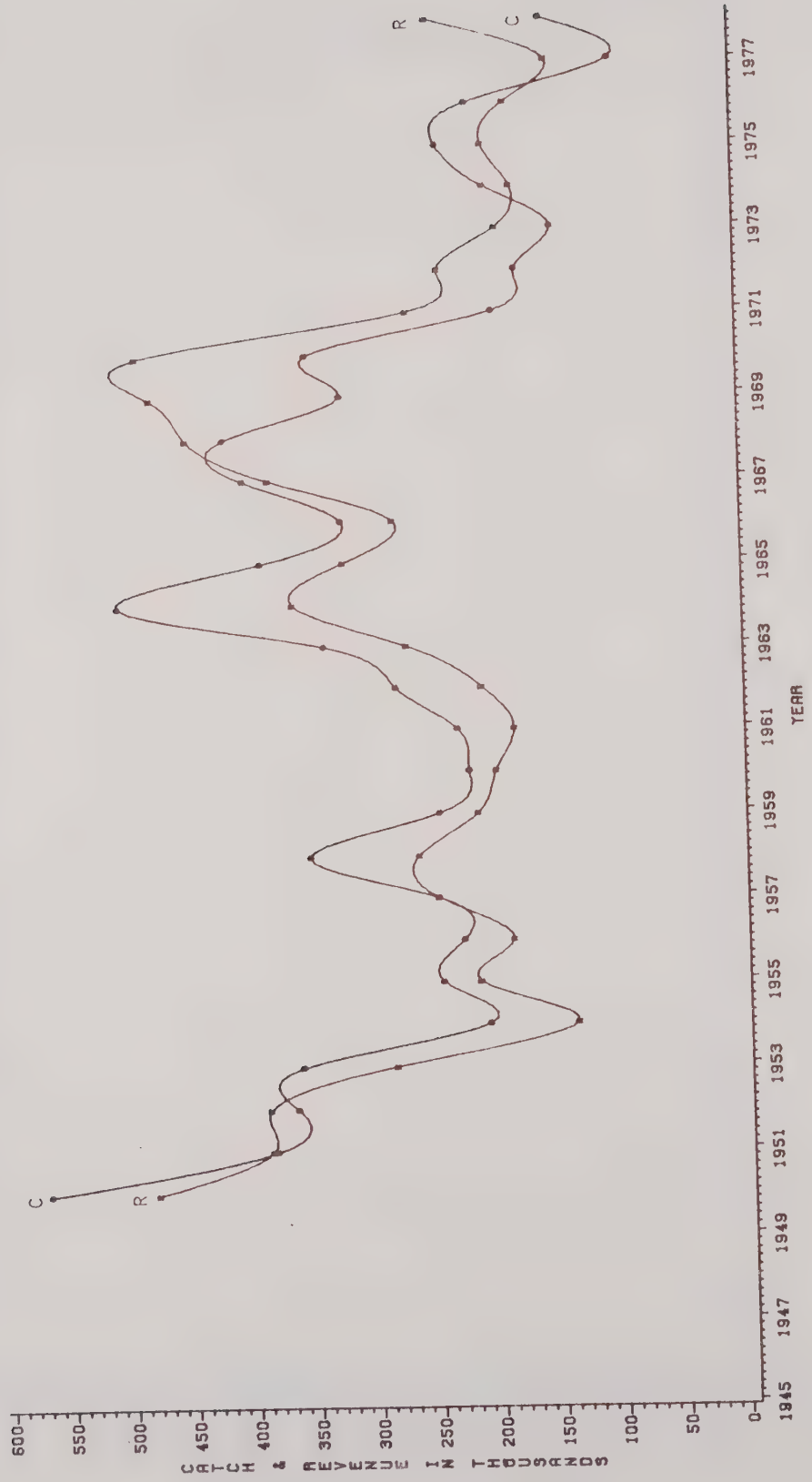


Figure 1-F.--Striped marlin. Plot of revenue in 1981 dollars and catch by year.

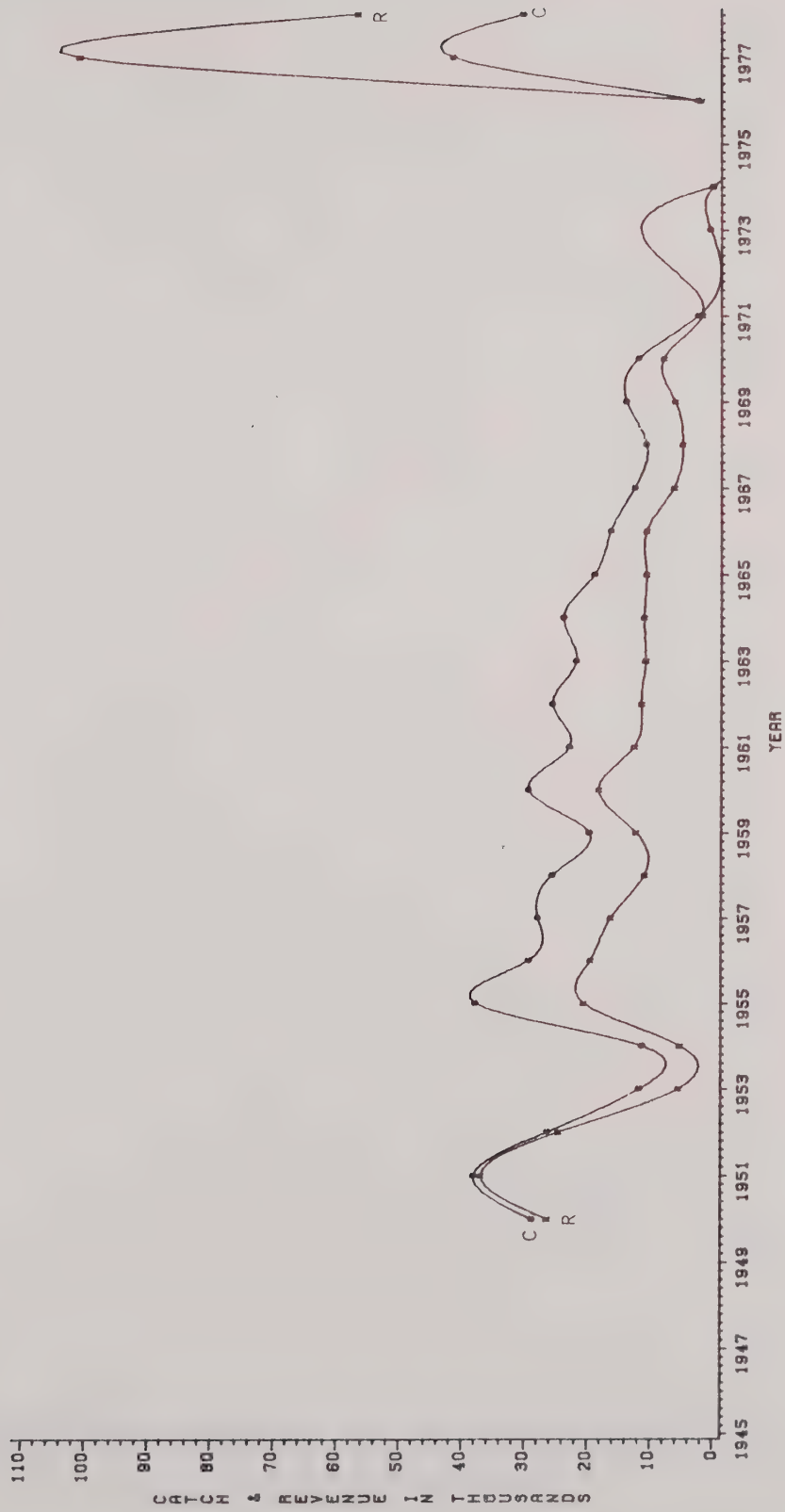


Figure 1-G.--Swordfish (broadbill). Plot of revenue in 1981 dollars and catch by year.

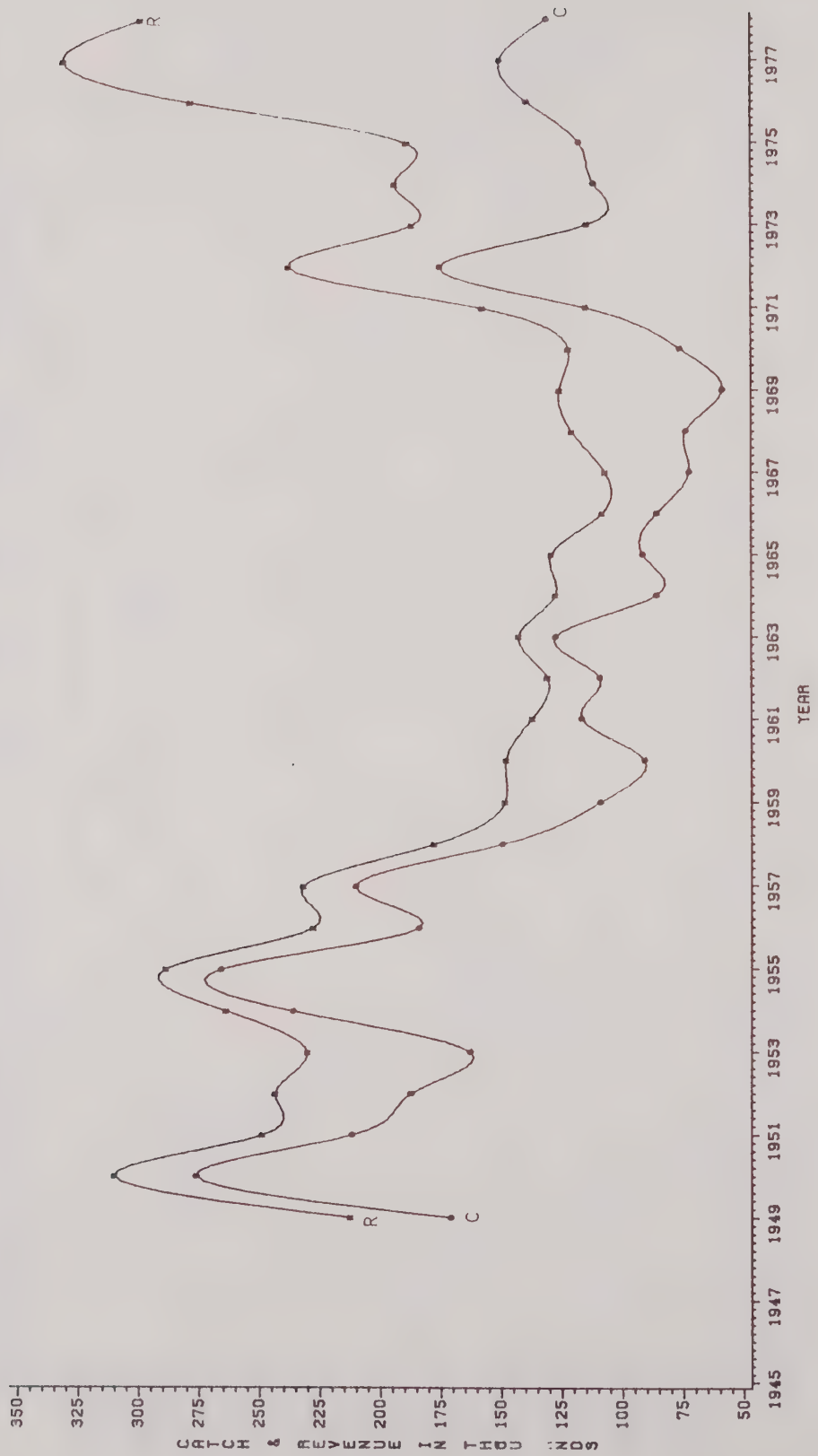


Figure 1-H.--Mahimahi. Plot of revenue in 1981 dollars and catch by year.

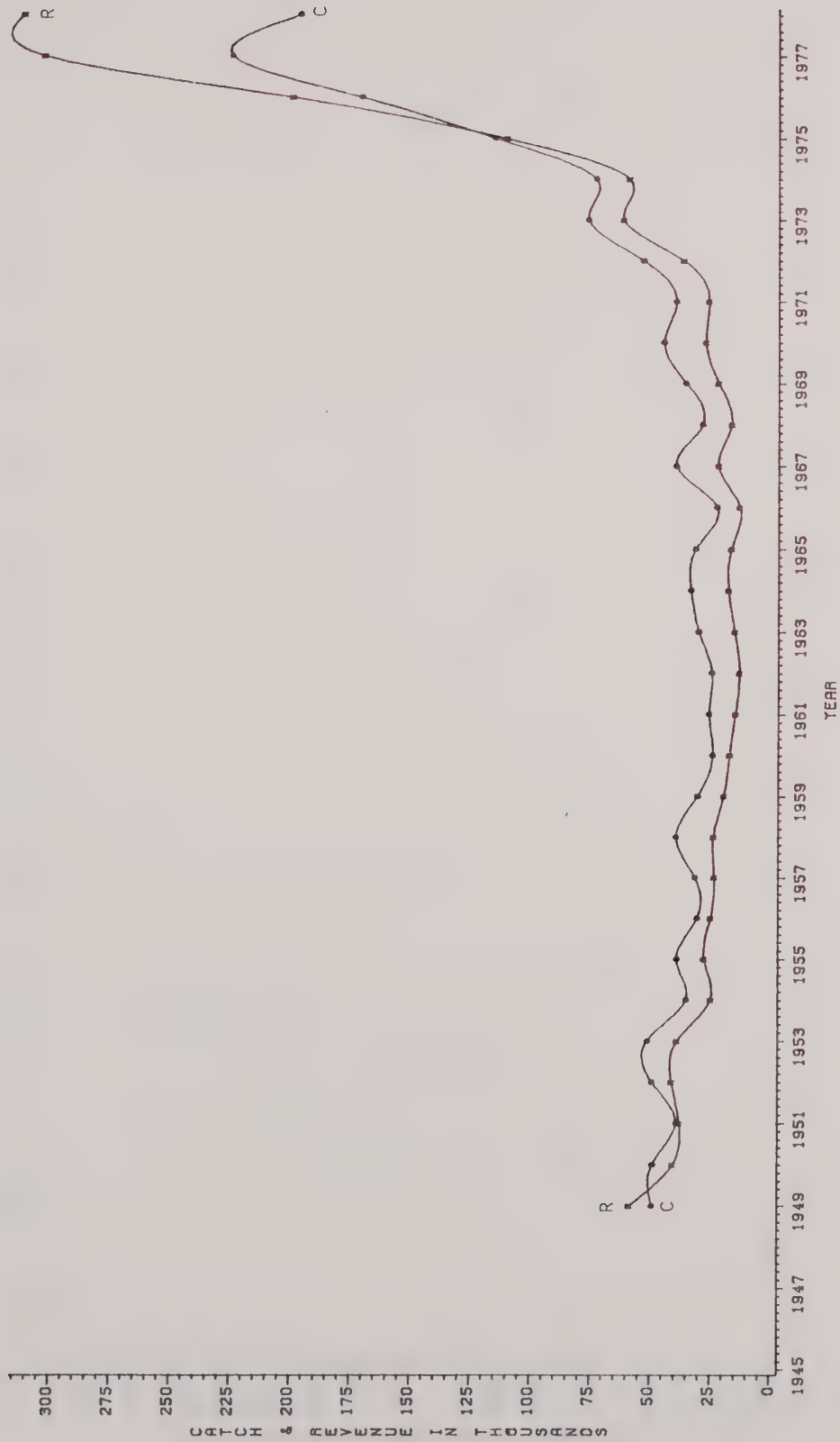


Figure 1-I.--Ono (wahoo). Plot of revenue in 1981 dollars and catch by year.

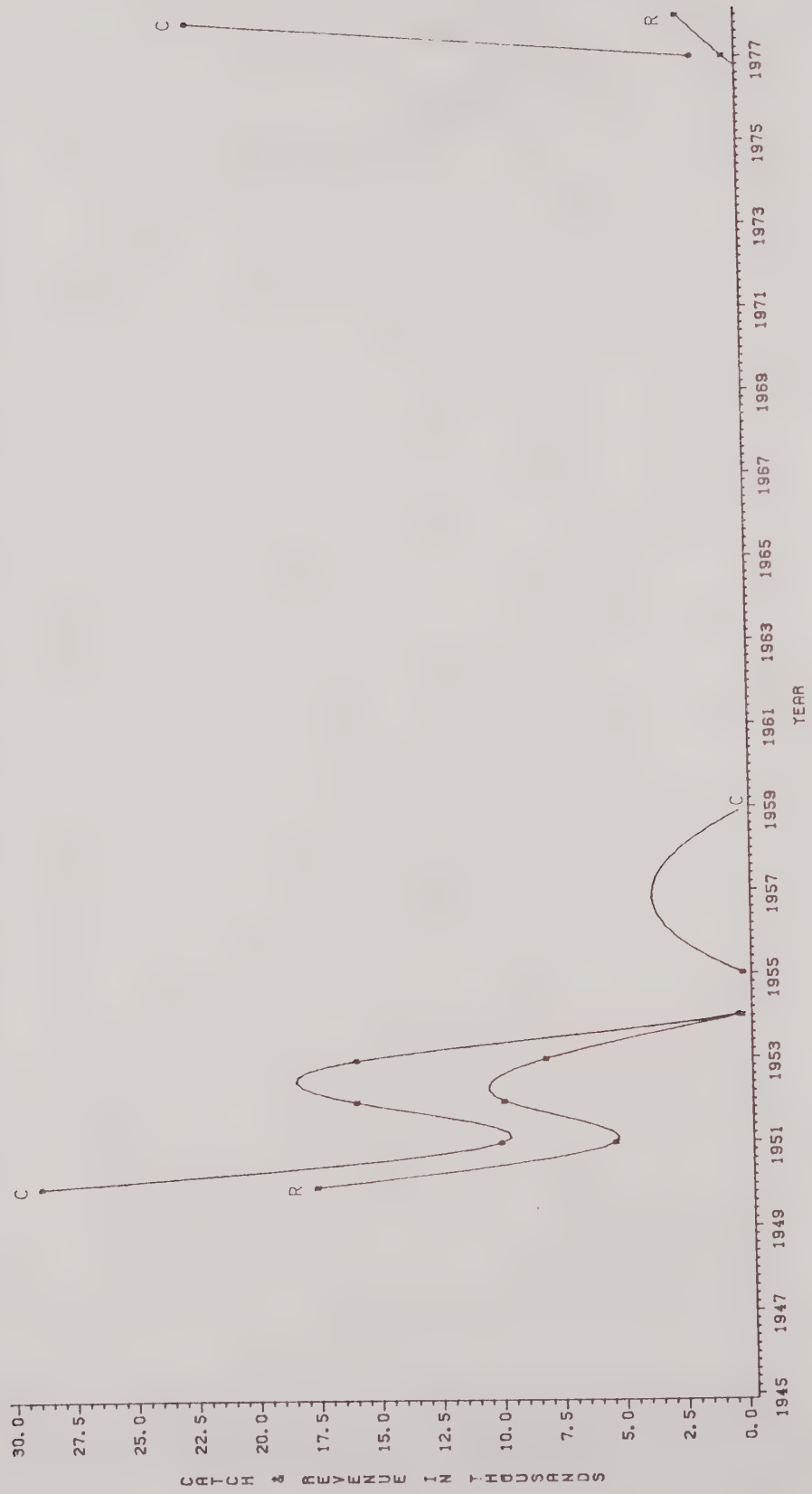


Figure 1-J.--Shark. Plot of revenue in 1981 dollars and catch by year.

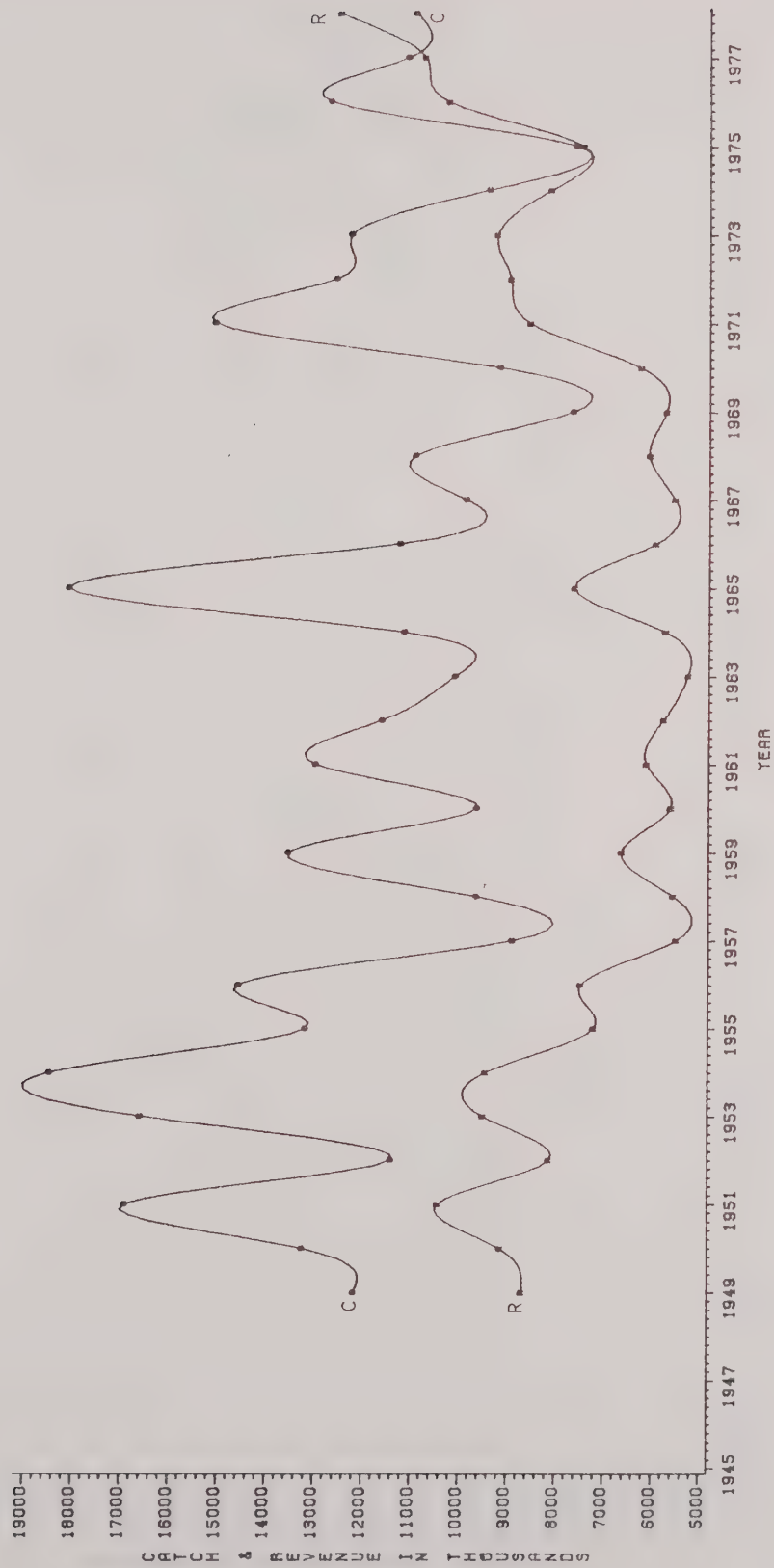


Figure 1-K.--Tunas and billfishes. Plot of revenue in 1981 dollars and catch by year.

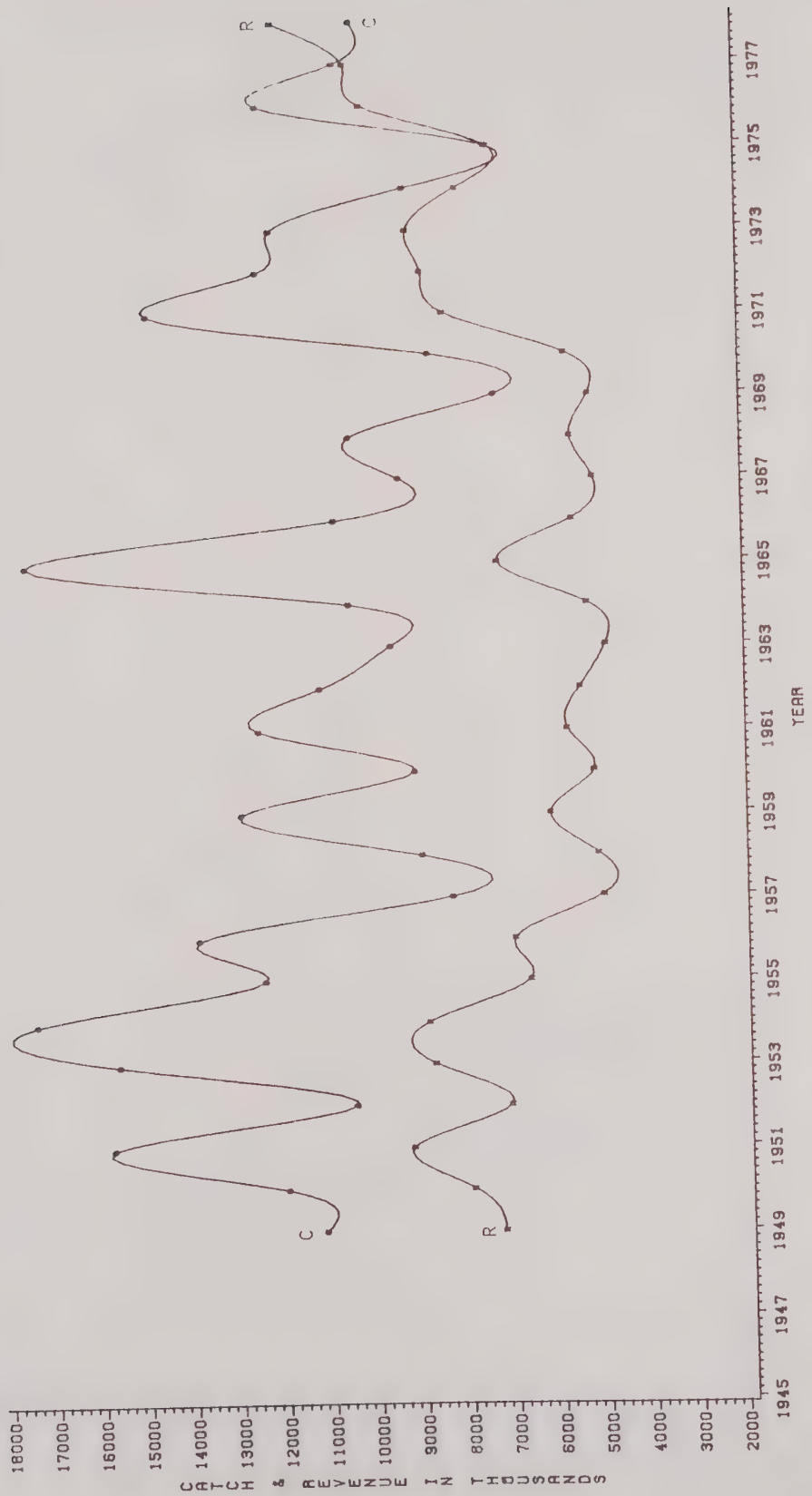


Figure 1-L.--Tunas. Plot of revenue in 1981 dollars and catch by year.

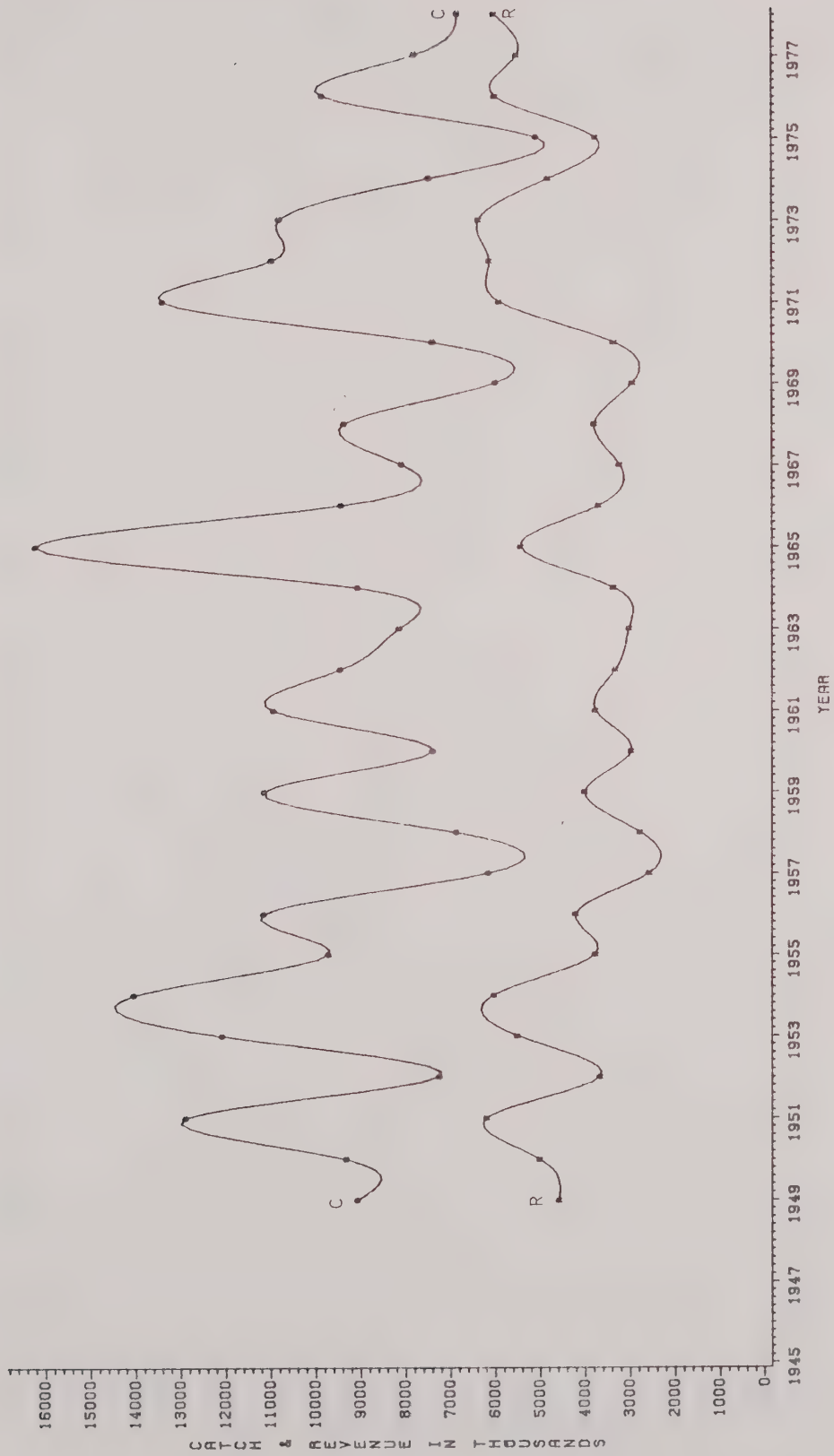


Figure 1-M.--Aku (skipjack tuna). Plot of revenue in 1981 dollars and catch by year.

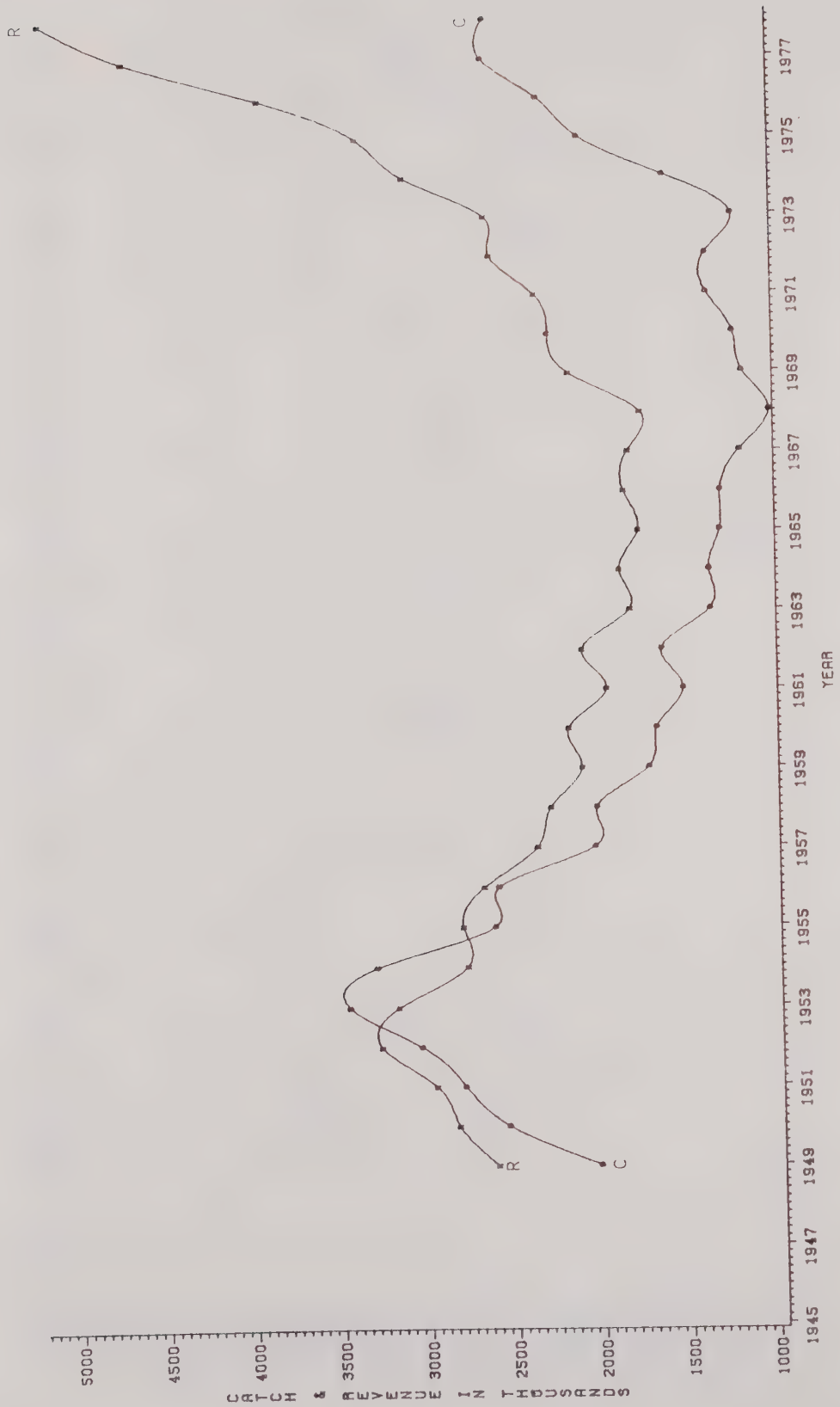


Figure 1-N.--Ahi (yellowfin tuna, bigeye tuna, and miscellaneous). Plot of revenue in 1981 dollars and catch by year.

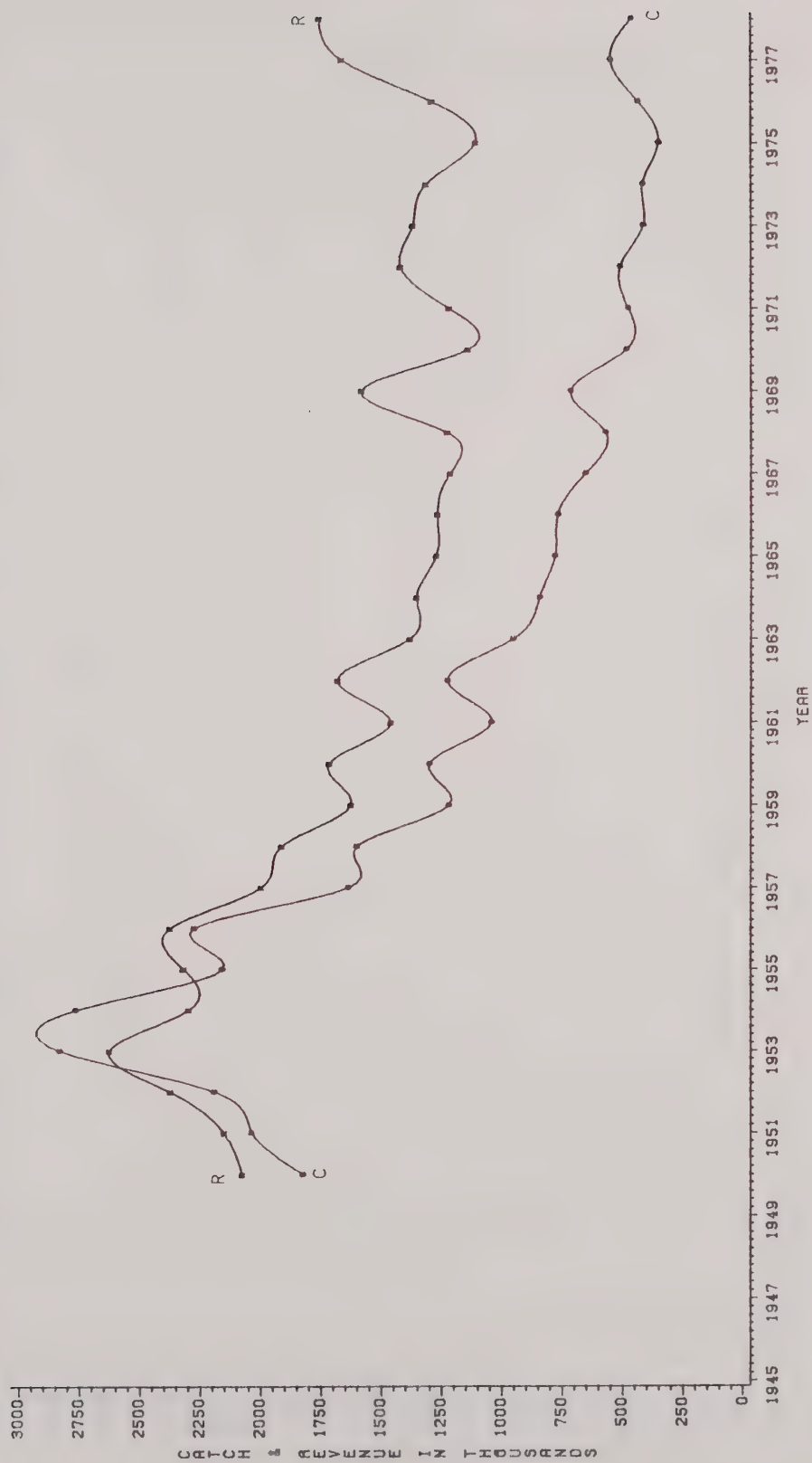


Figure 1-0.--Ahi (bigeye tuna). Plot of revenue in 1981 dollars and catch by year.

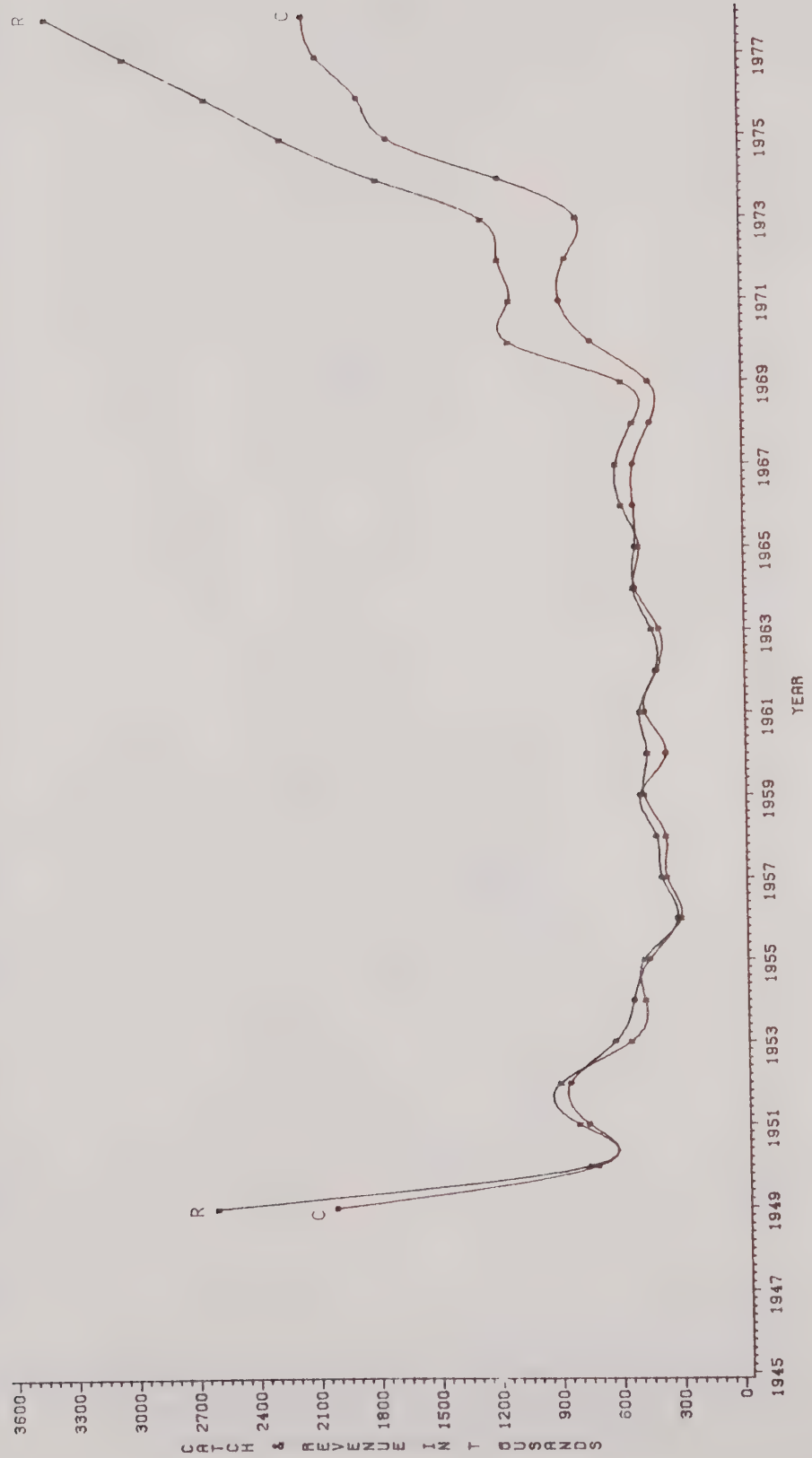


Figure 1-P.--Ahi (yellowfin tuna). Plot of revenue in 1981 dollars and catch by year.

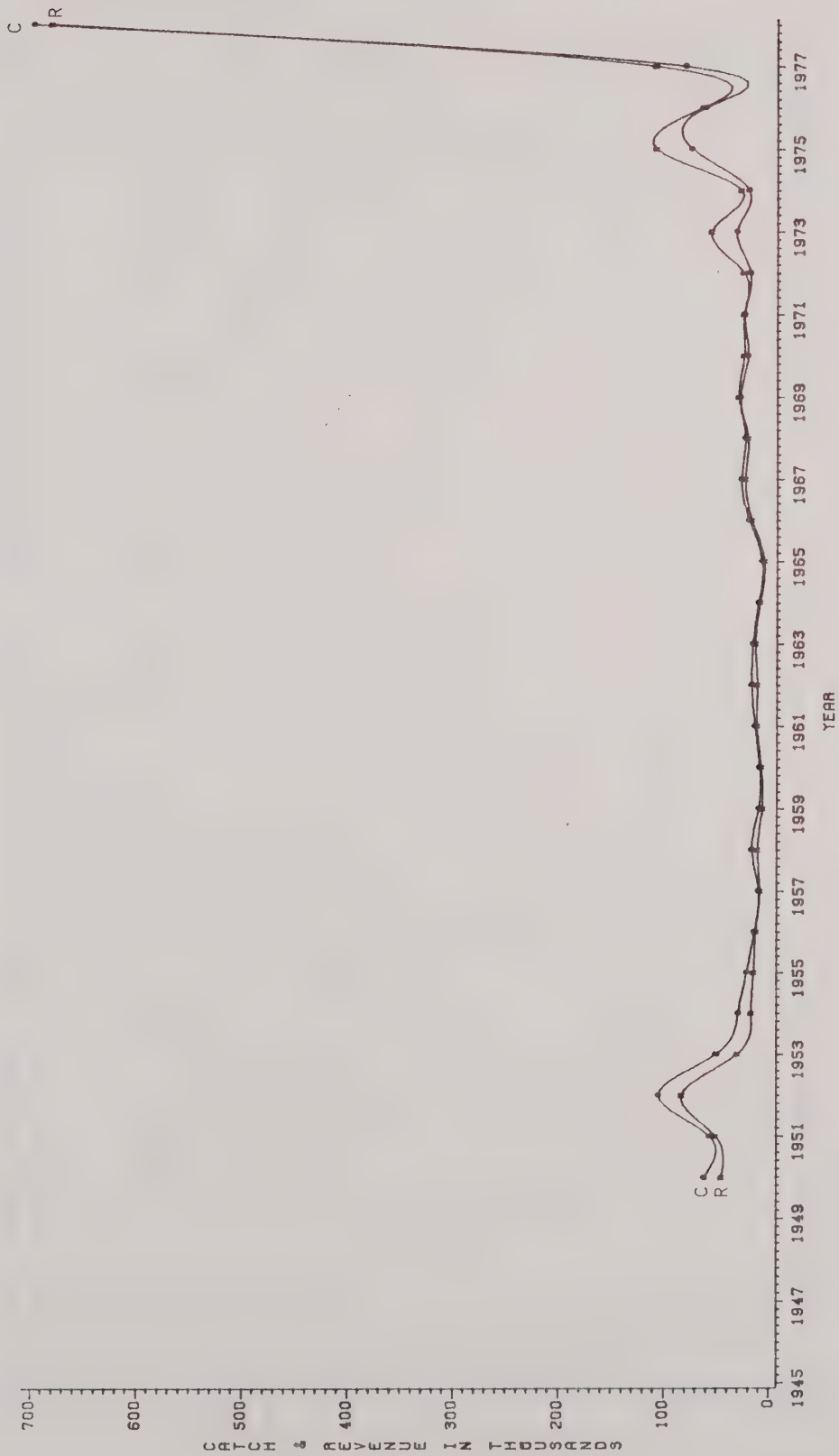


Figure 1-Q.--Ahipalaha (albacore). Plot of revenue in 1981 dollars and catch by year.

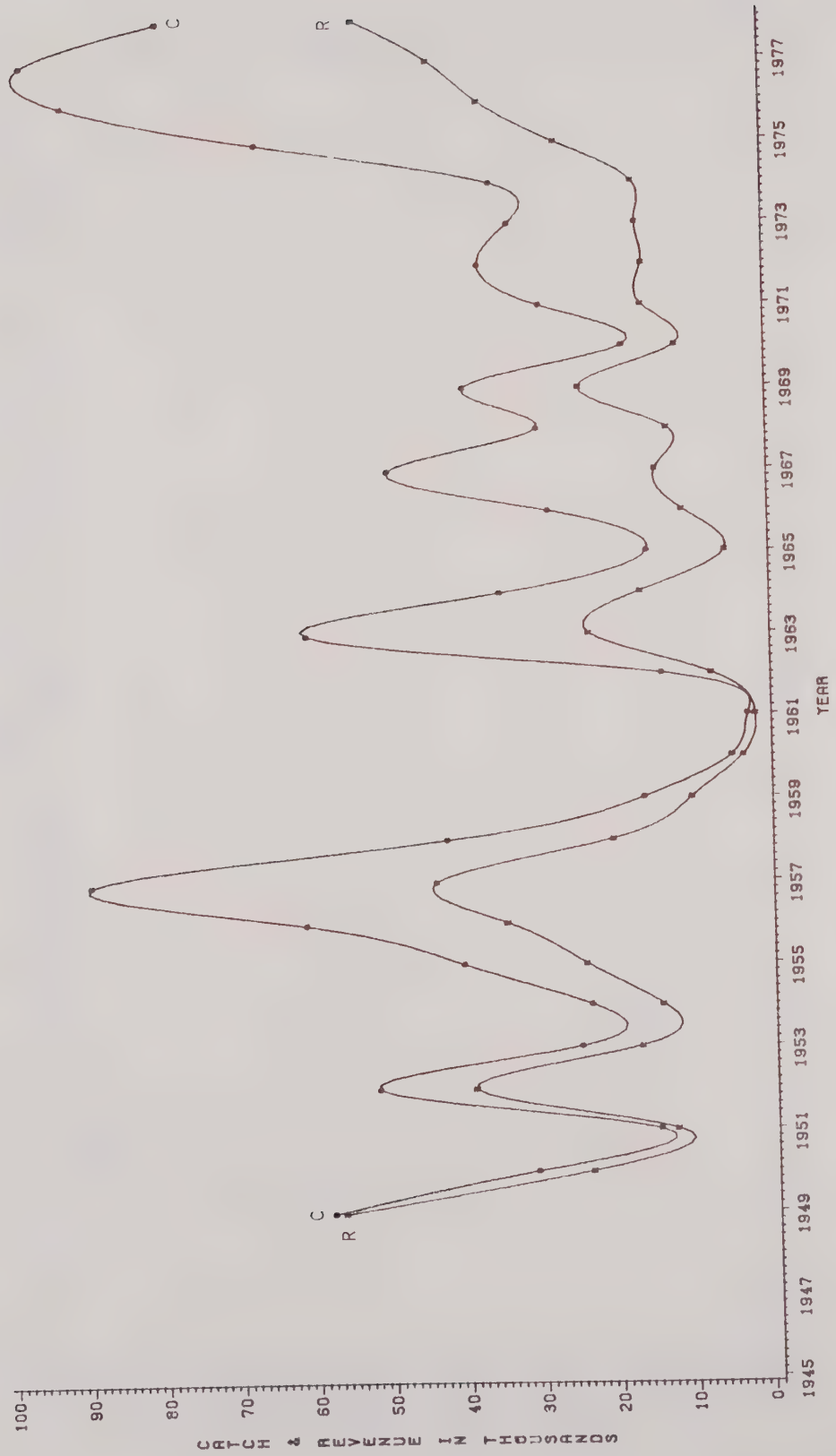


Figure 1-R.--Kawakawa. Plot of revenue in 1981 dollars and catch by year.

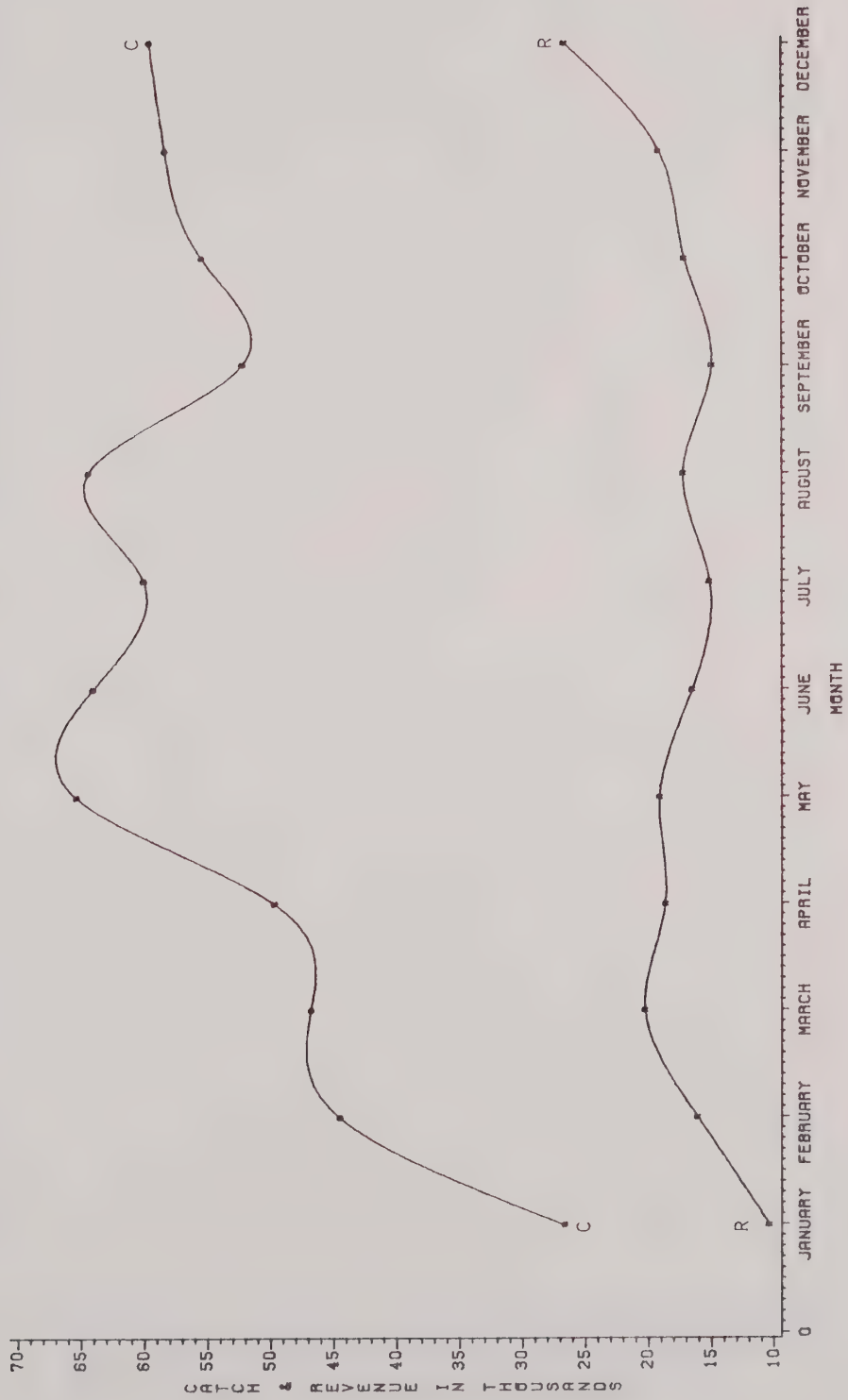


Figure 2-A.--Billfishes. Plot of revenue and catch by month (1949-78).

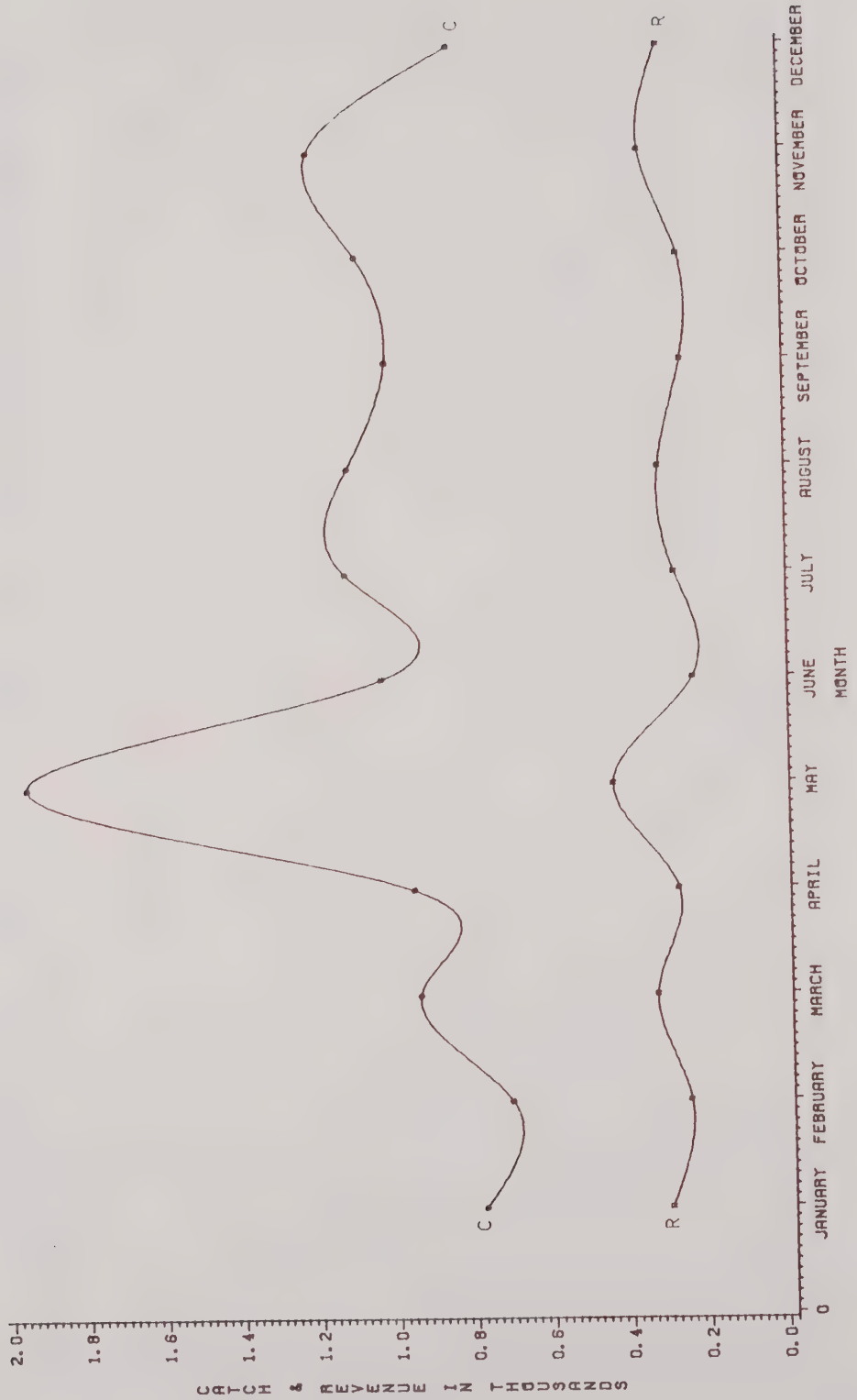


Figure 2-B.--Black marlin. Plot of revenue and catch by month (1949-78).

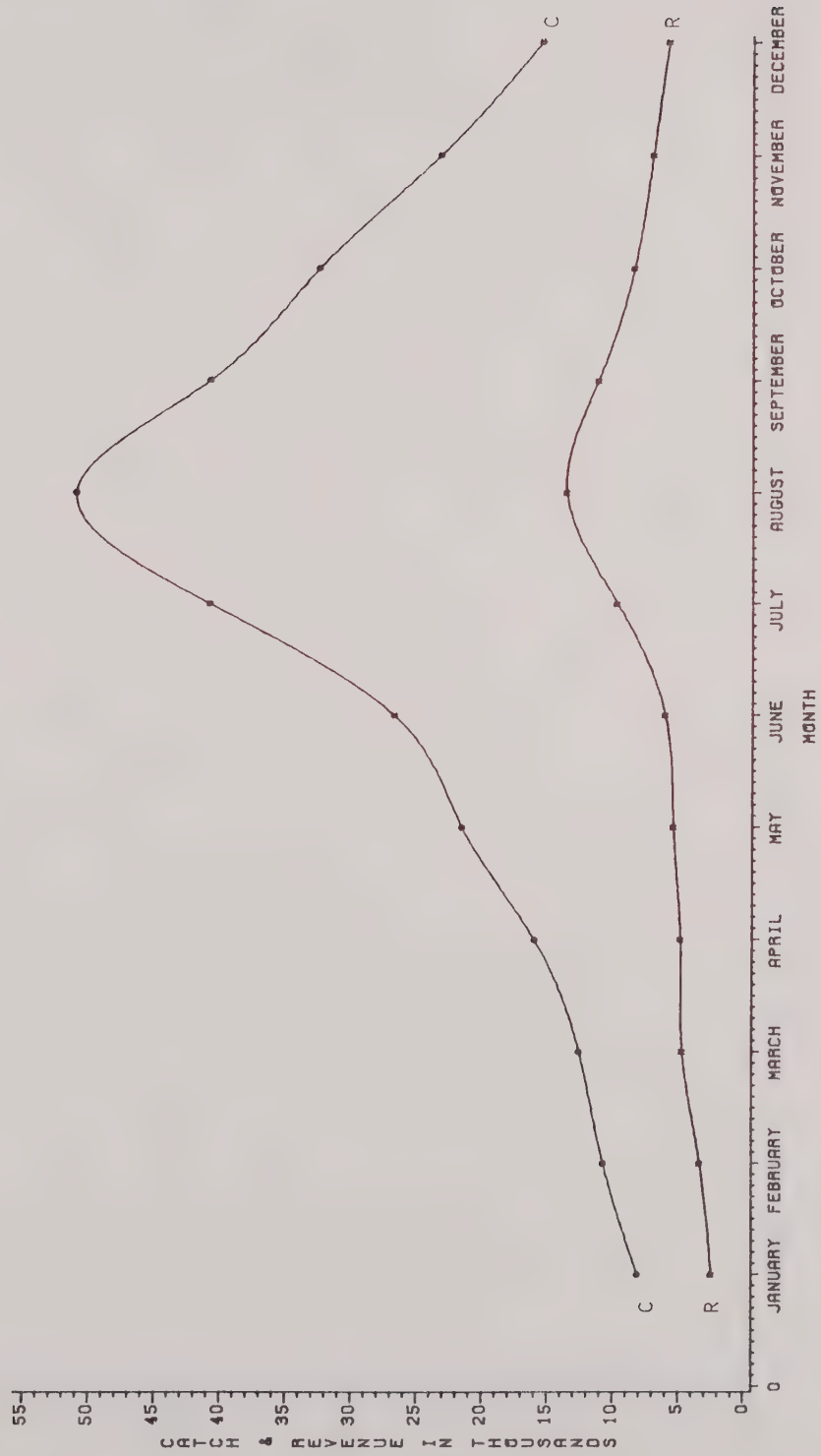


Figure 2-C.--Blue marlin. Plot of revenue and catch by month (1949-78).

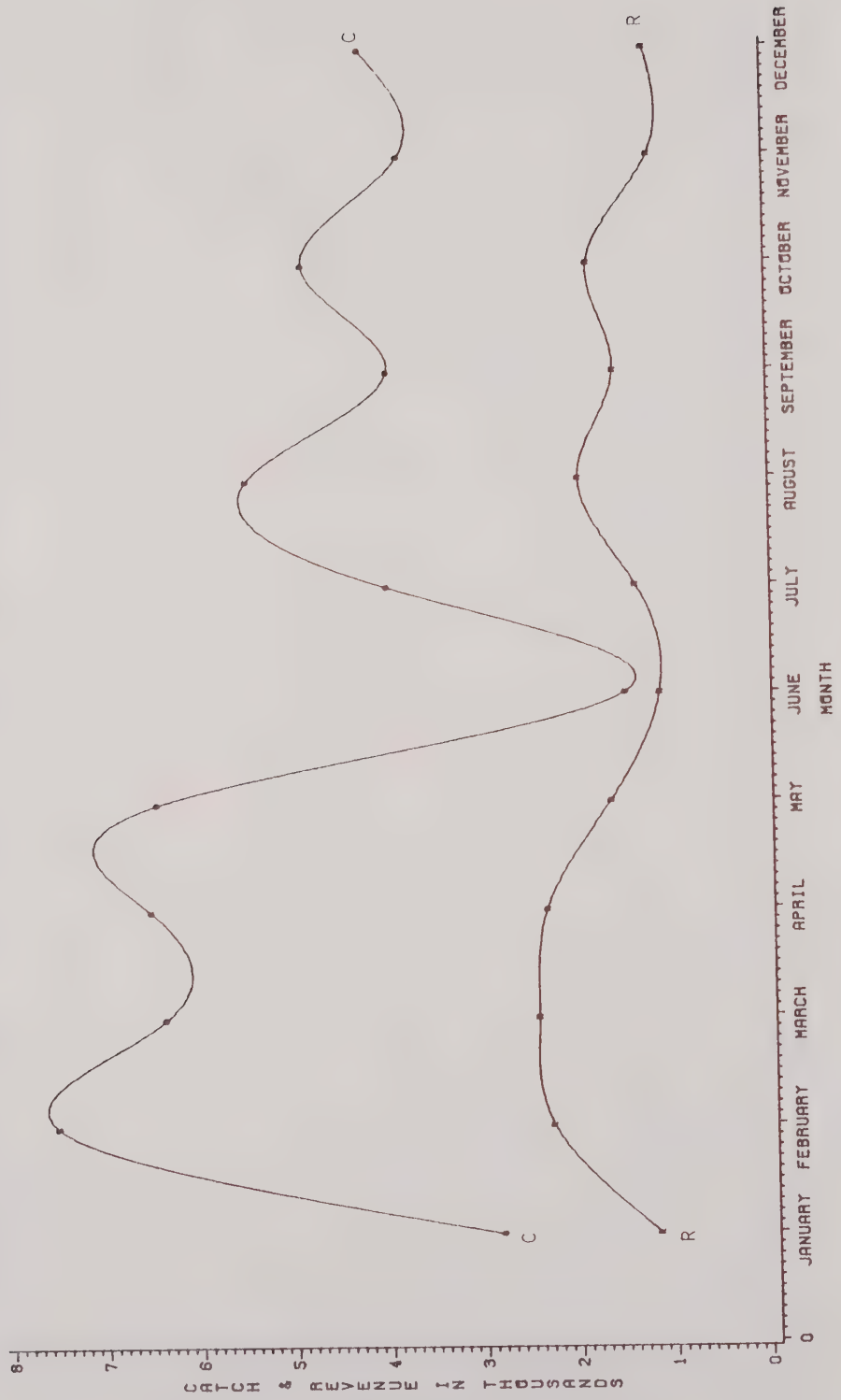


Figure 2-D.--Sailfish. Plot of revenue and catch by month (1949-78).

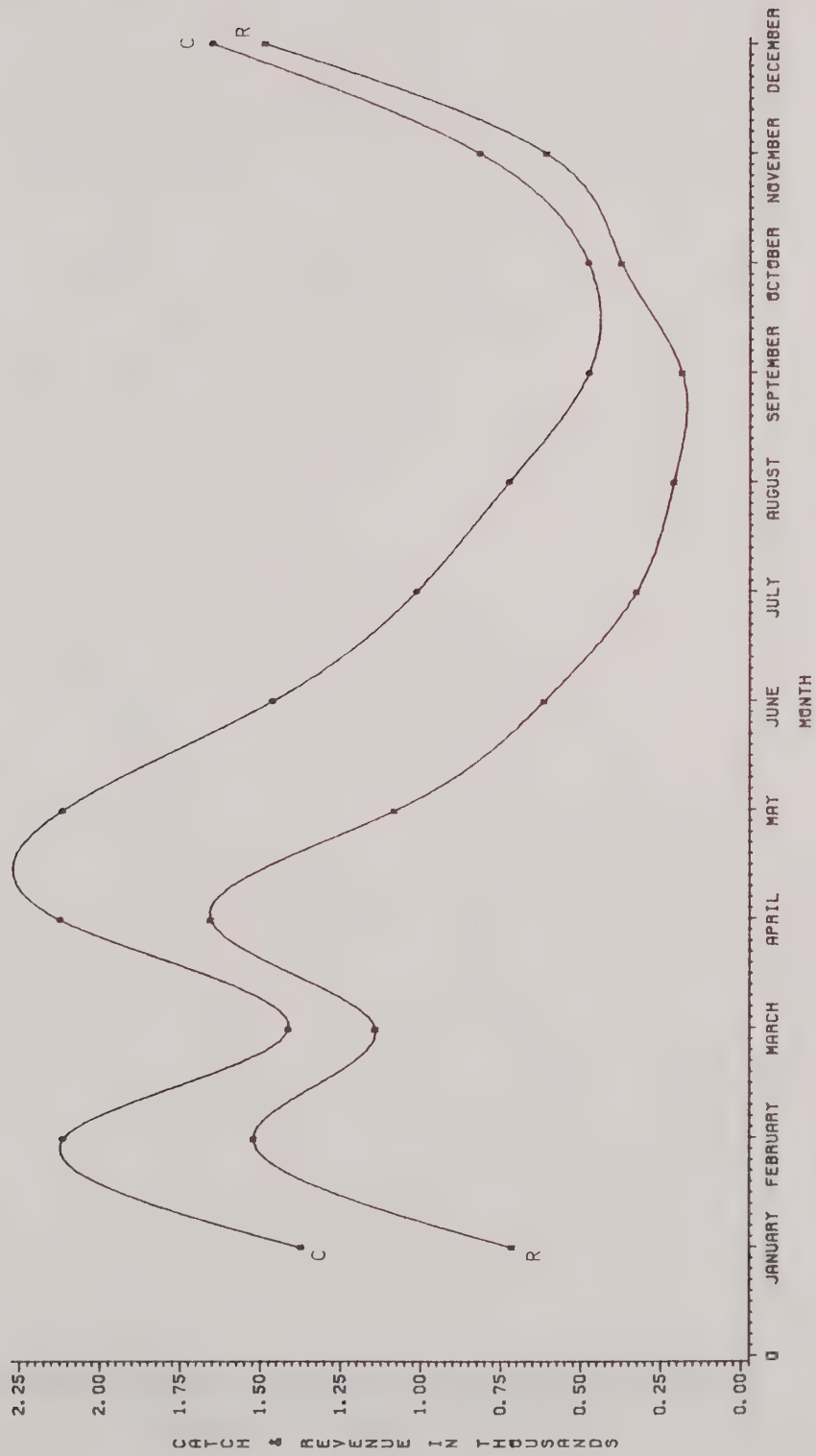


Figure 2-E.--Shortbill spearfish. Plot of revenue and catch by month (1949-78).

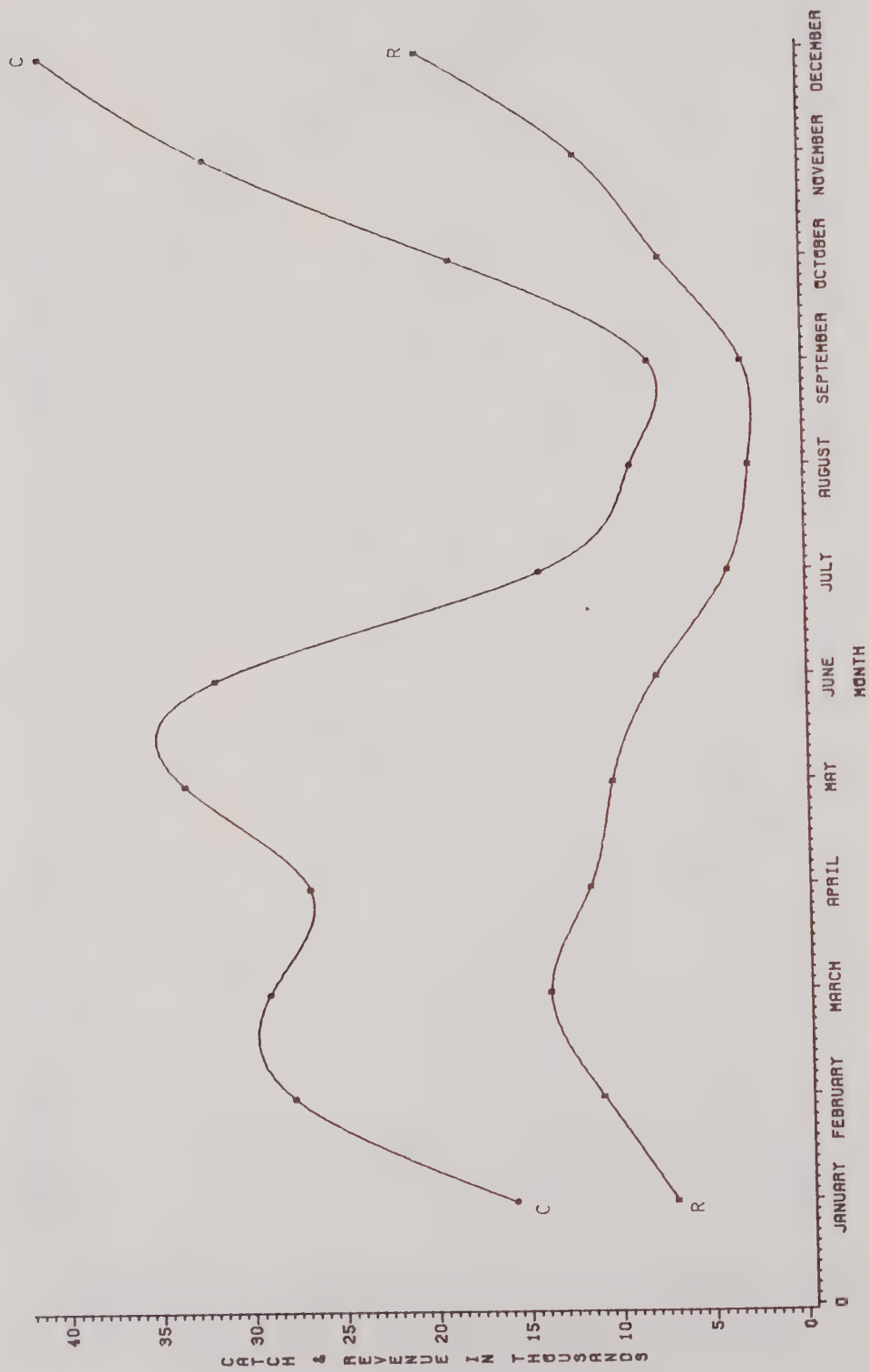


Figure 2-F.--Striped marlin. Plot of revenue and catch by month (1949-78).

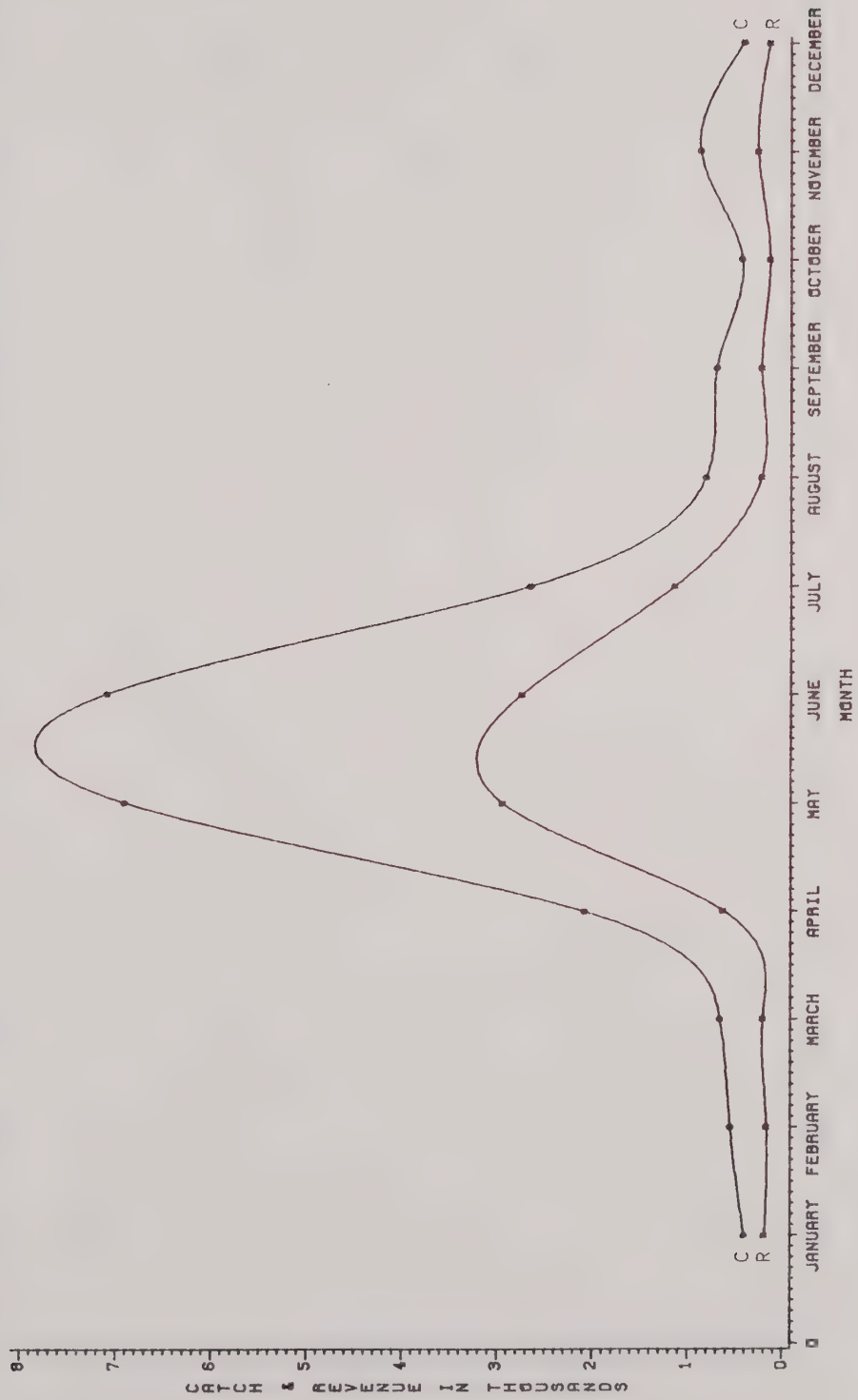


Figure 2-G.--Swordfish (broadbill). Plot of revenue and catch by month (1949-78).

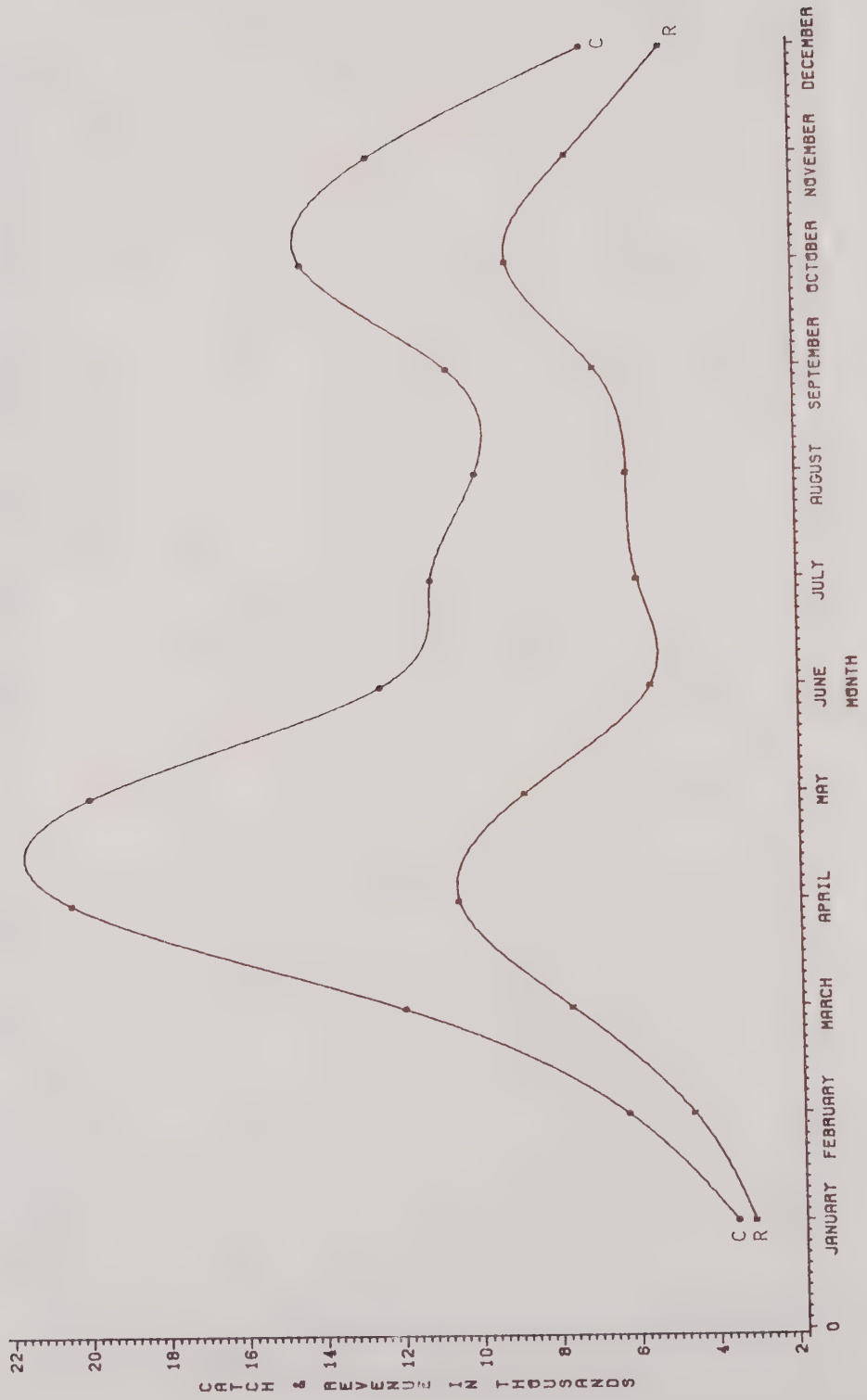


Figure 2-H.--Mahimahi. Plot of revenue and catch by month (1949-78).



Figure 2-I.--Ono (wahoo). Plot of revenue and catch by month (1949-78).

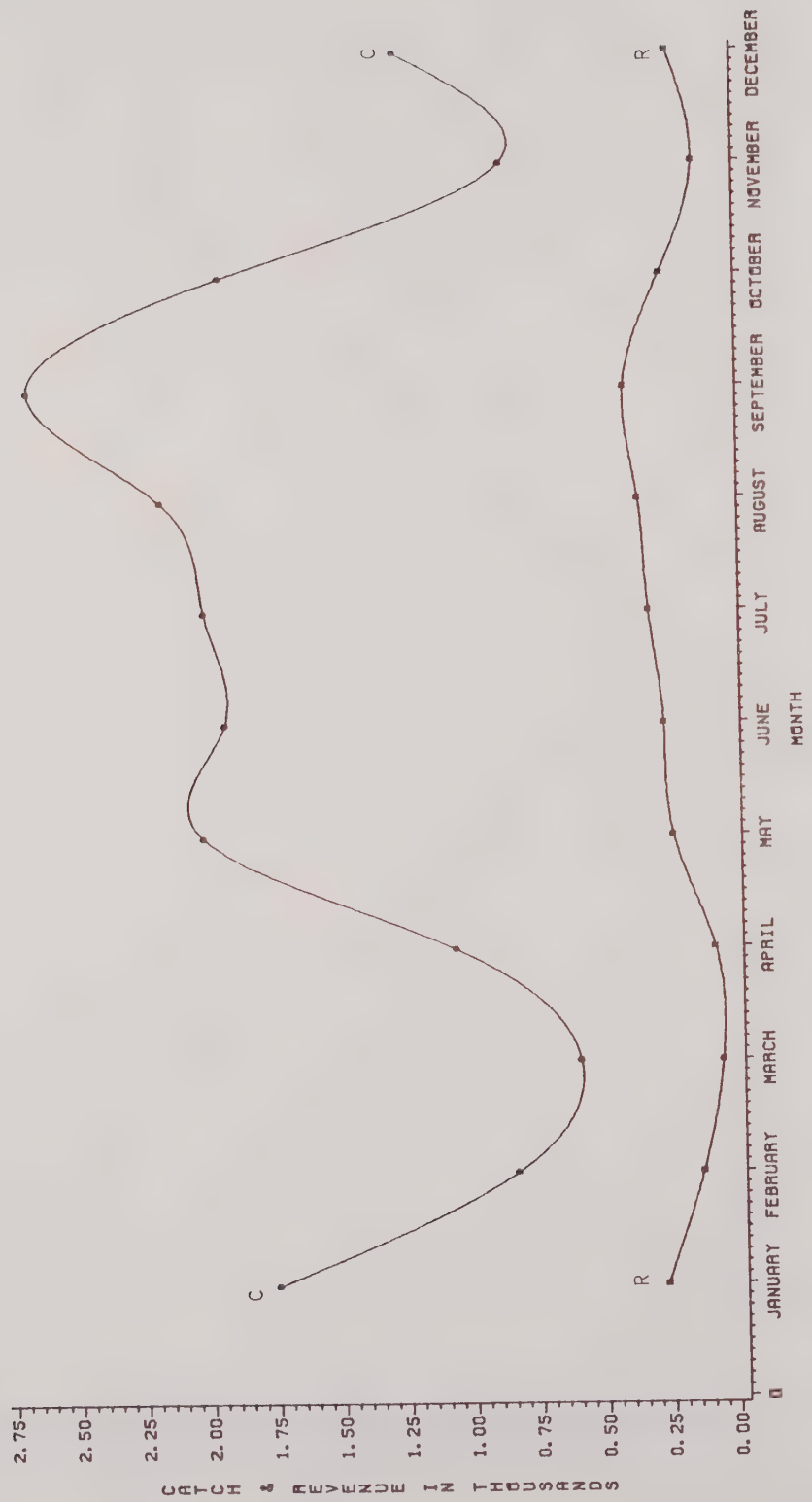


Figure 2-J.--Shark. Plot of revenue and catch by month (1949-78).

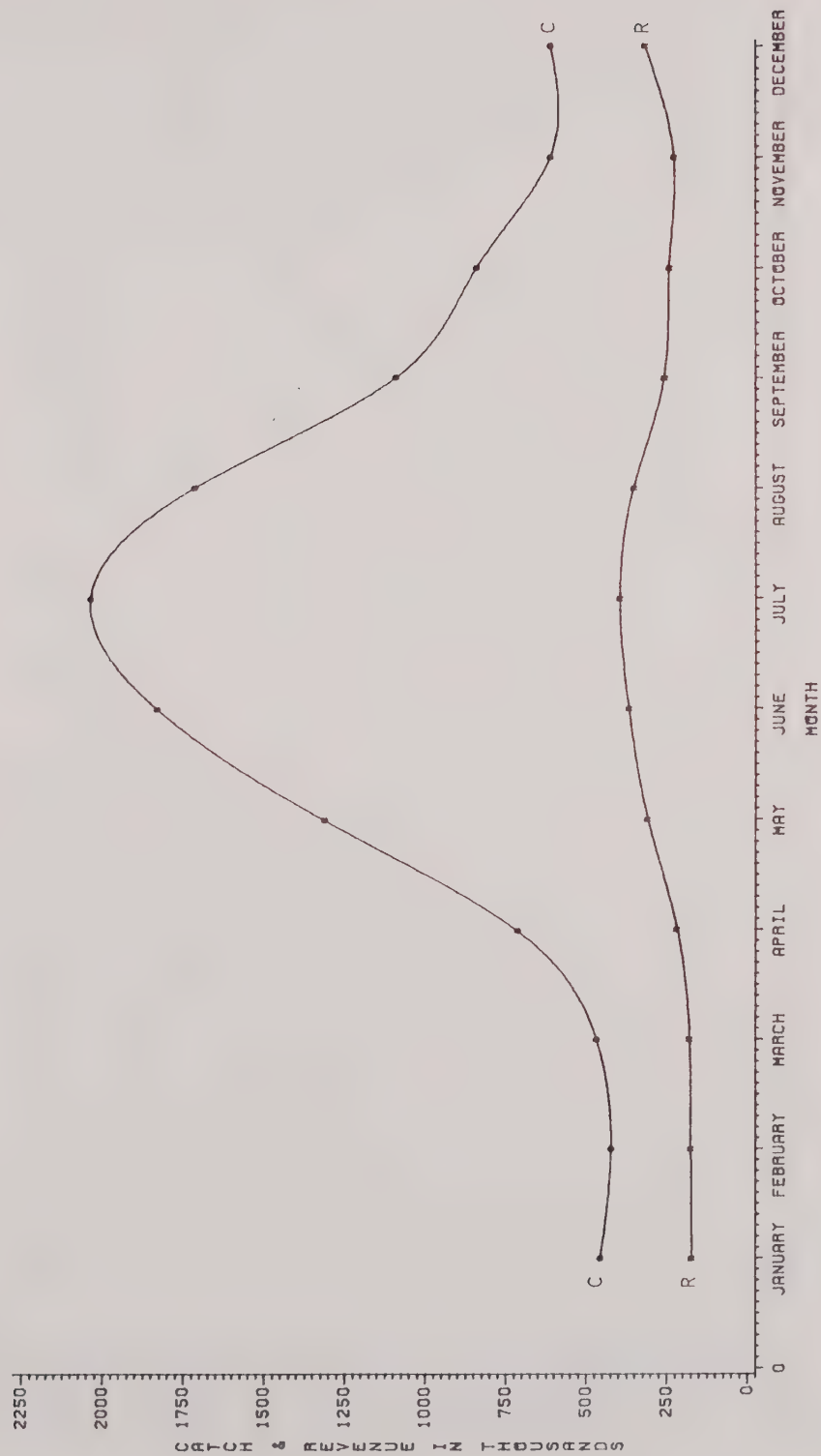


Figure 2-K.--Tunas and billfishes. Plot of revenue and catch by month (1949-78).

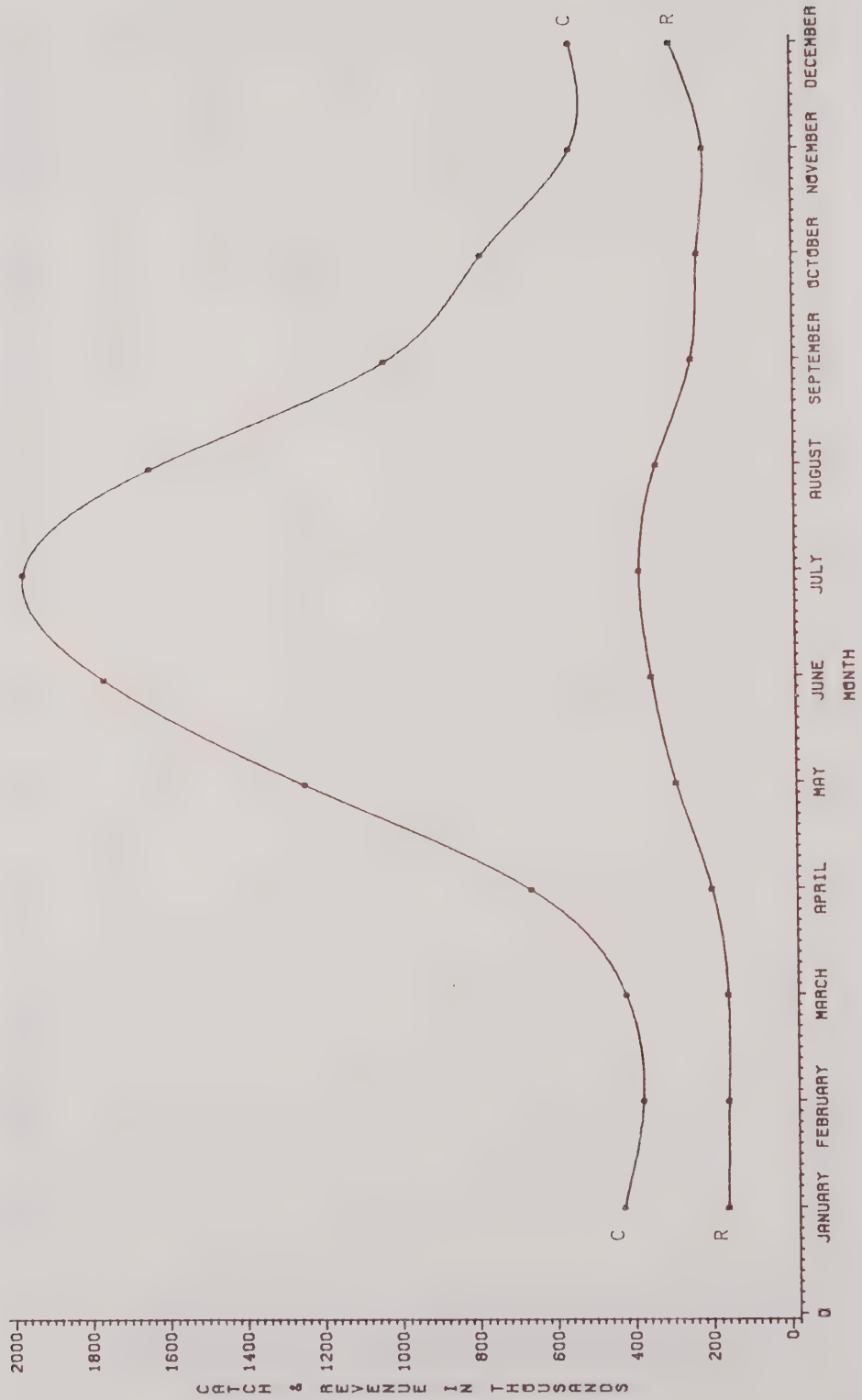


Figure 2-L.--Tunas. Plot of revenue and catch by month (1949-78).

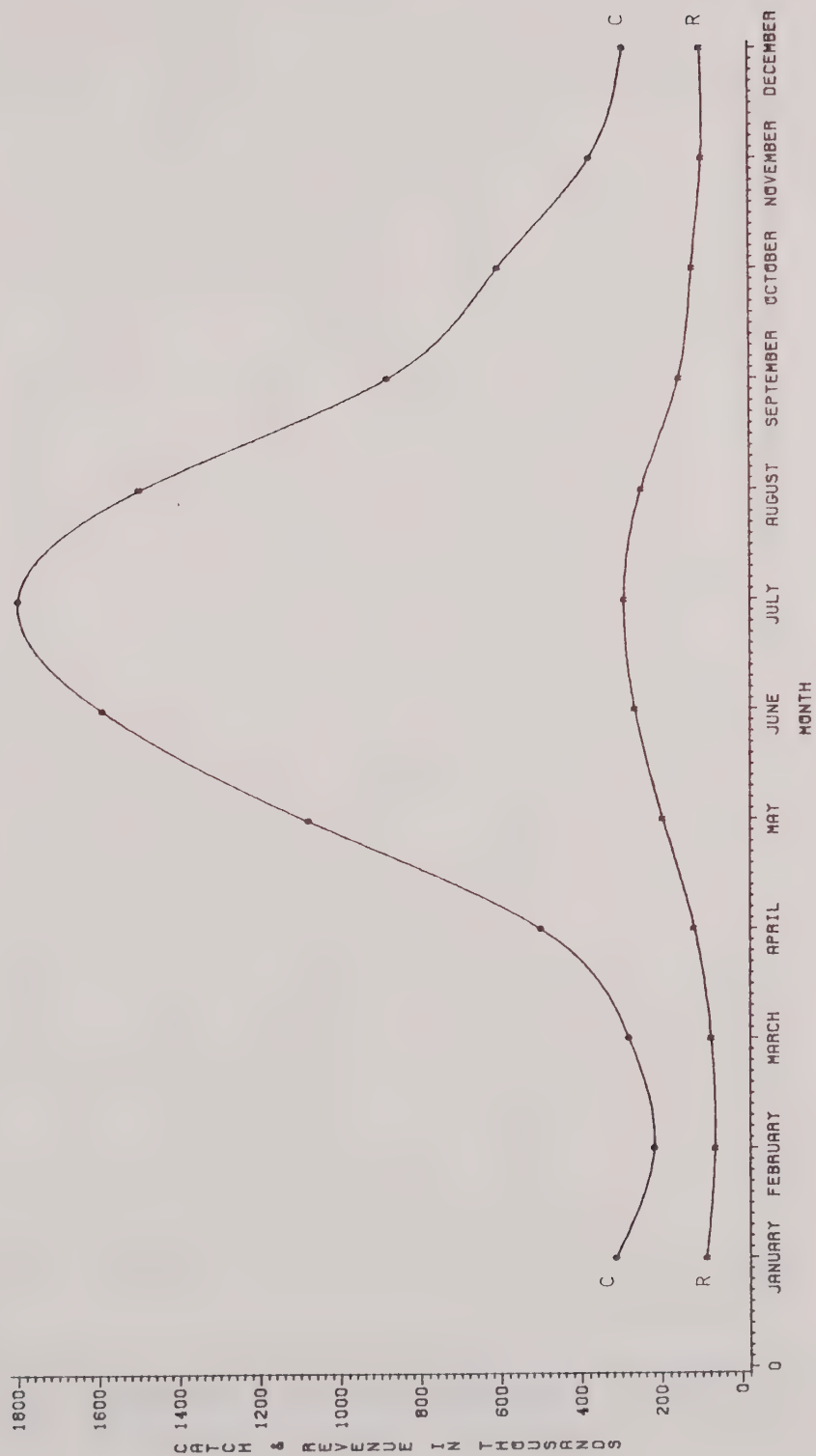


Figure 2-M.--Aku (skipjack tuna). Plot of revenue and catch by month (1949-78).

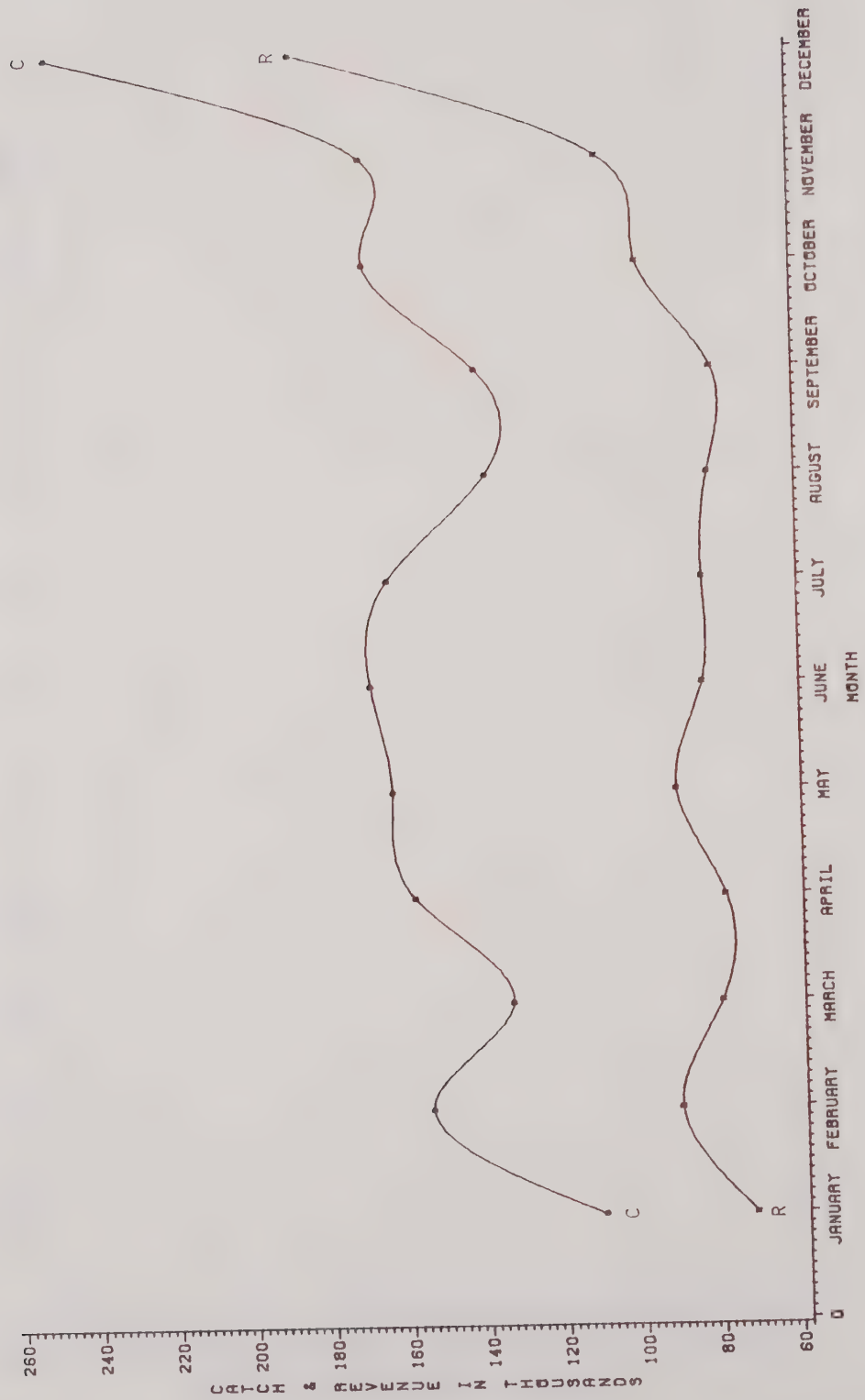


Figure 2-N.--Ahi (yellowfin tuna, bigeye tuna, and miscellaneous. Plot of revenue and catch by month (1949-78).

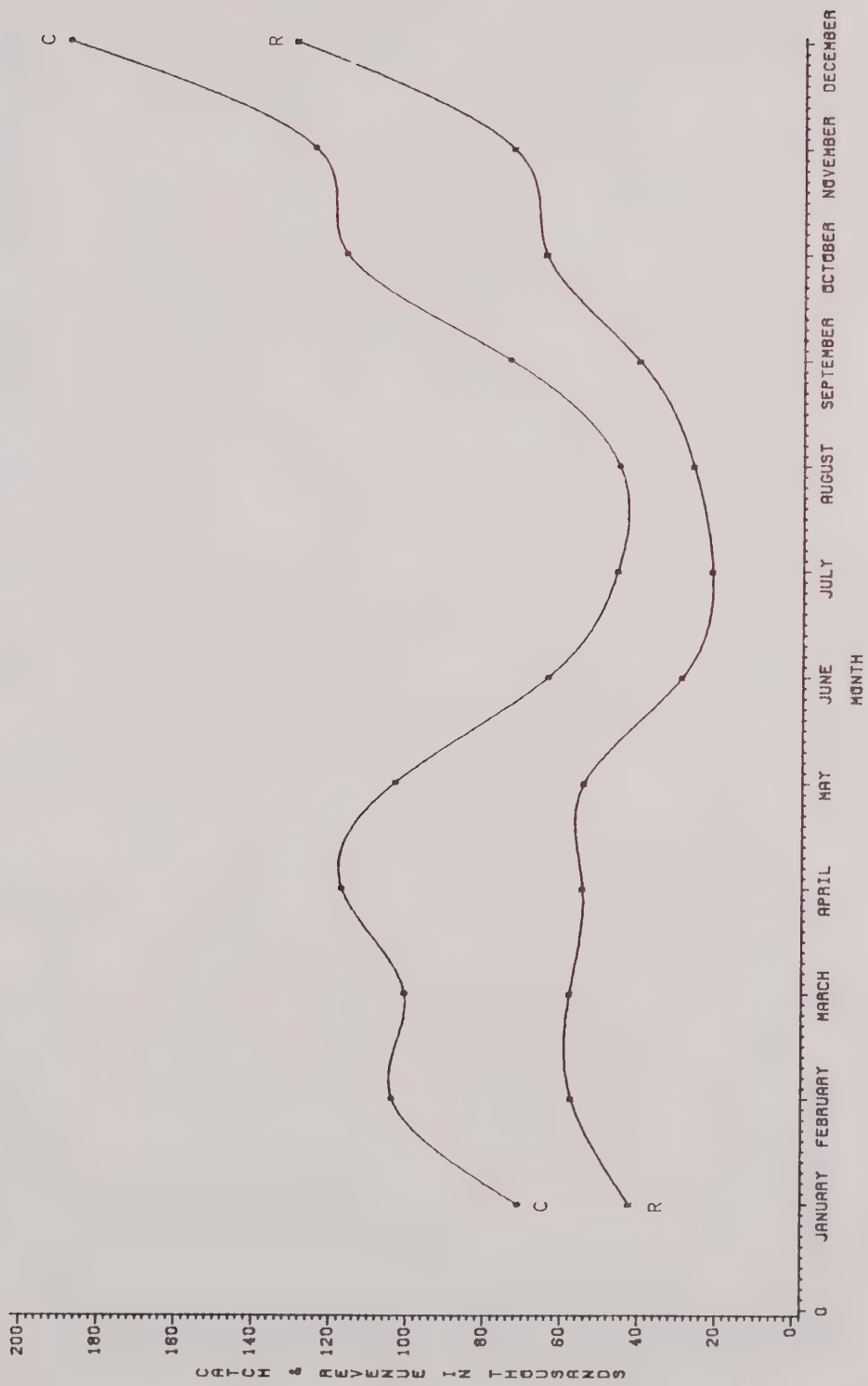


Figure 2-0.--Ahi (bigeye tuna). Plot of revenue and catch by month (1949-78).

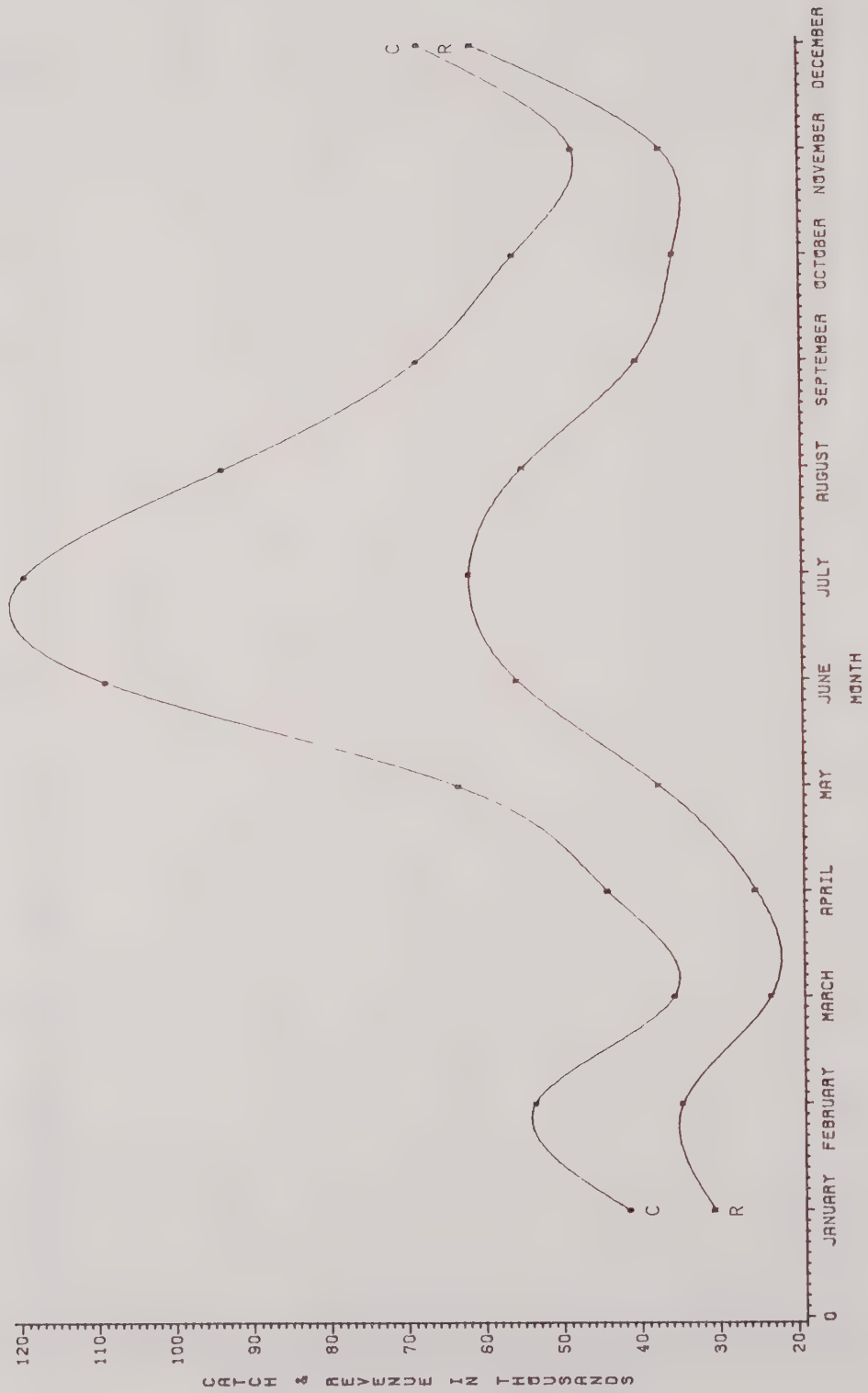


Figure 2-P.--Ahi (yellowfin tuna). Plot of revenue and catch by month (1949-78).

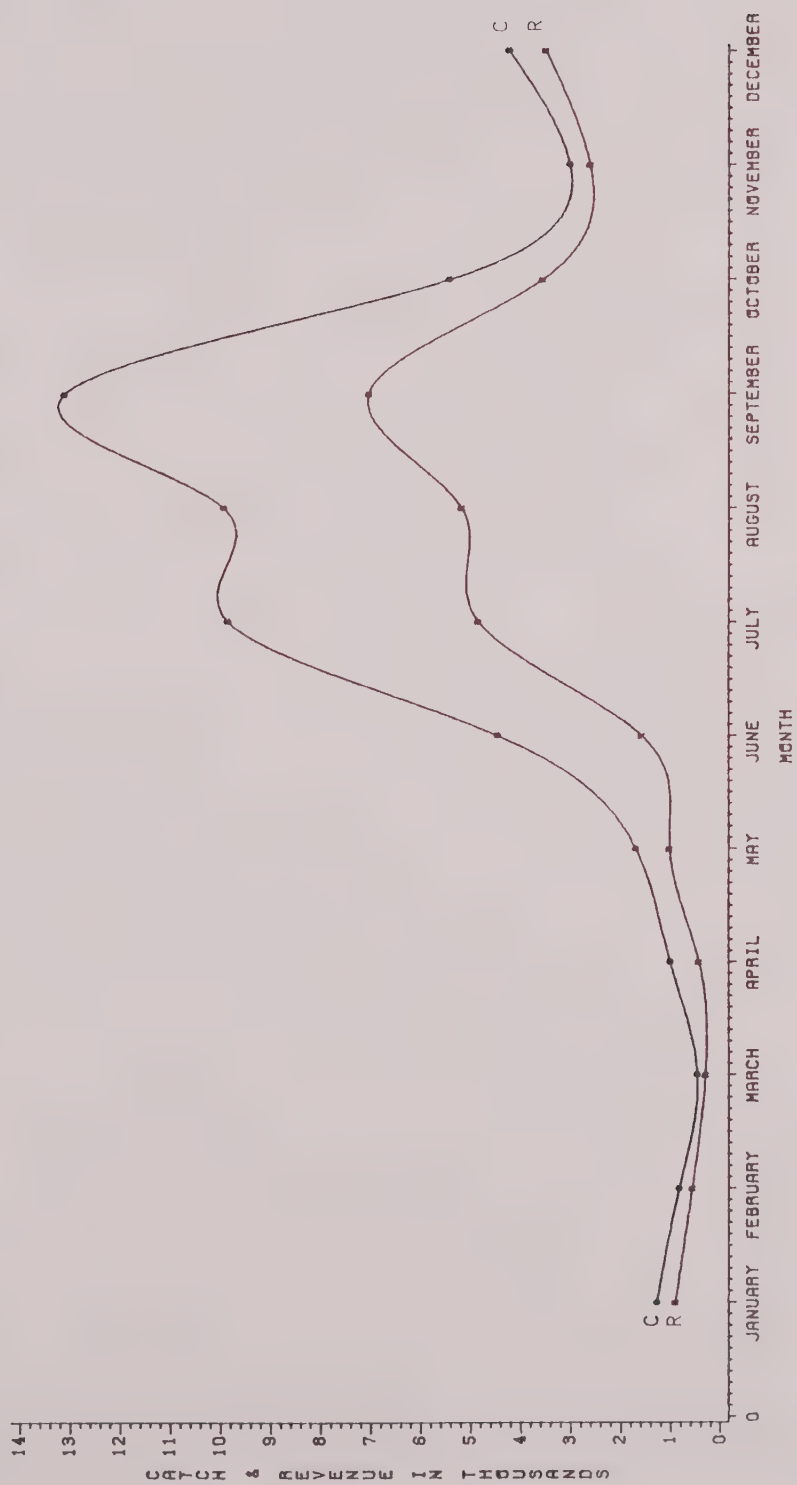


Figure 2-Q.--Ahipalaha (albacore). Plot of revenue and catch by month (1949-78).

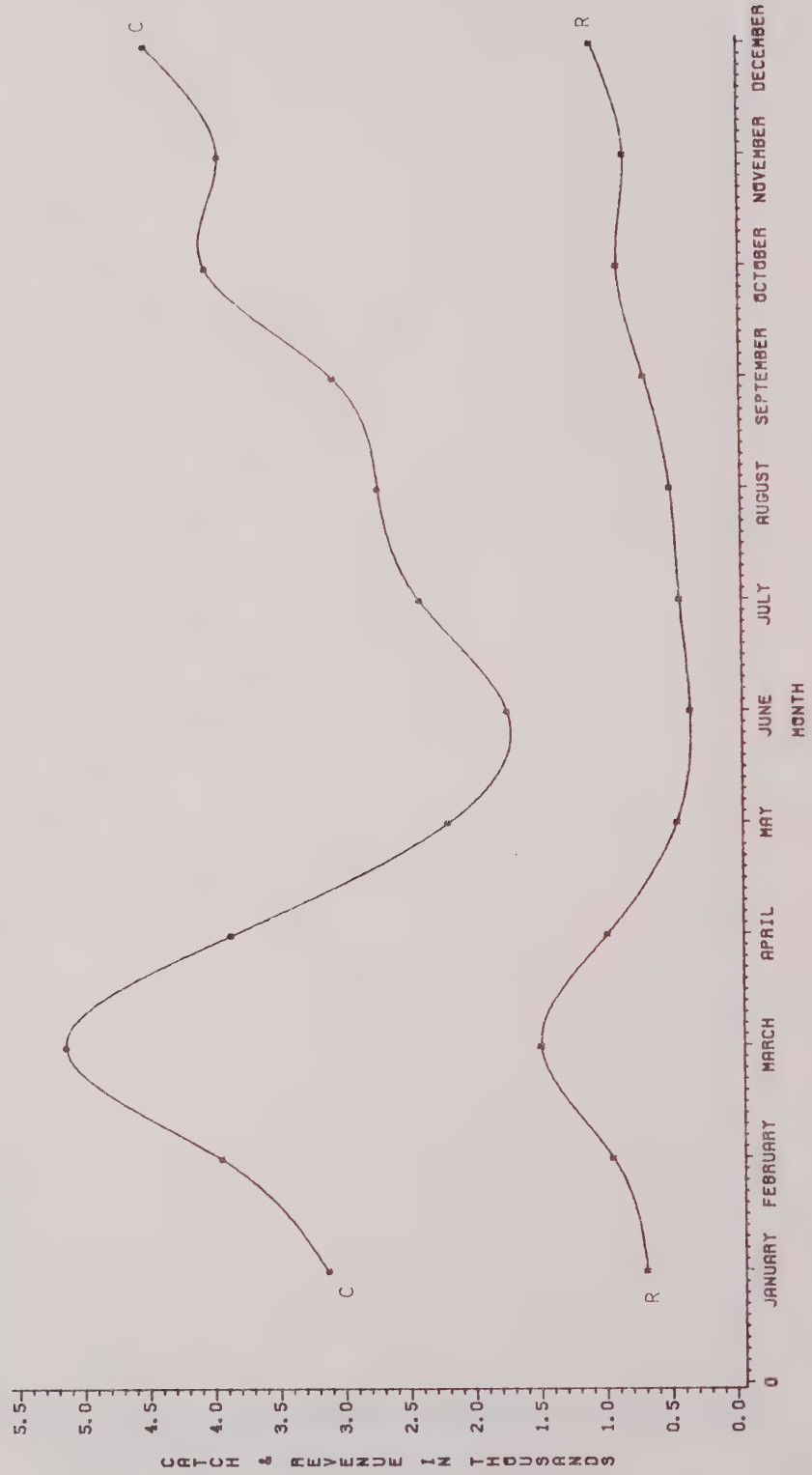


Figure 2-R.--Kawakawa. Plot of revenue and catch by months (1949-78).



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PROVIDING LARVAL FISH AS FOOD FOR LARVAE OF SKIPJACK TUNA:
INVESTIGATIONS ON INDUCED SPAWNING OF MANINI, OR CONVICT
SURGEONFISH (Acanthurus triostegus sandvicensis):

10/11/83
National Marine Fisheries Service
2570 Dole Street
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November 1983

NOT FOR PUBLICATION

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This report was prepared under contract (83-JJA-00347) by Calvin M. Kaya. The main objectives of this study were to develop suitable methods for inducing spawning in the convict surgeonfish (Acanthurus triostegus sandvicensis) and to test the suitability of the resulting larvae as a food fish for larval and juvenile tuna. Since this report was prepared under contract, the statements, findings, and conclusions herein are those of the contractor and do not necessarily reflect the view of the National Marine Fisheries Service.

Richard W. Brill
Leader, Experimental Ecology of
Tunas Program

November 29, 1983

Preface

It was mutually agreed between myself and Dr. Richard Brill, in charge of experimental investigations at the Kewalo Research Facility, that the original objectives of this study program should be modified to include and emphasize the development of techniques to produce, on demand, fish larvae of a non-tuna species. Such larvae could then be available to feed to tuna larvae as part of the ongoing program to rear young tuna in captivity at the Kewalo Research Facility. The original study included two aspects: (1) experimental determination of optimum temperatures and upper and lower median thermal tolerance limits for embryos and prolarvae of skipjack tuna; and (2) investigation of a possible mechanism for "stress-induced spawning" of skipjack tuna. In the revised study program, efforts to induce spawning of a non-tuna species replaced the proposed work on stress-induced spawning and was assigned primary emphasis. The experiments on temperature relations of embryos and prolarvae were to be retained but given secondary priority.

The experimental apparatus for maintaining embryos and prolarvae at six different temperatures was set up and its functioning tested and confirmed ready for initiation of these investigations. However, this part of the study did not progress beyond this. The Kewalo Research Facility was not able to acquire live adult tuna to spawn and produce the fertilized eggs to commence these experiments, within the 30-day contracted period or within an additional two weeks that I made myself available.

The following report, therefore, will include only the work on induced spawning of a non-tuna species, the manini or convict surgeonfish.

Providing Larval Fish as Food for Larvae of Tuna: Investigations on Induced Spawning of Manini, or Convict Surgeonfish (Acanthurus triostegus sandvicensis).

Introduction

The purpose of this study was to attempt to develop techniques to artificially induce spawning of manini at the Kewalo Research Facility and thereby to provide, on demand, fish larvae as food for young skipjack tuna being reared in captivity. Larvae of these tuna have been hatched out and reared at the Kewalo Research Facility up to an age of two weeks posthatch. However, larvae from one batch of eggs sent to the La Jolla Laboratory were reared beyond two weeks and one specimen lived for 35 days before dying of accidental causes. Although the reasons for this difference in survival have not been determined, it is suspected that an important factor was the feeding of fish larvae (halibut) to the skipjack larvae reared at La Jolla. Investigators at both laboratories fed the same species of cultured rotifers and copepods to the tuna larvae, but fish larvae of the appropriate size for this purpose have not been available at the Kewalo Research Facility.

Manini were selected for this study for several reasons. One is that they are very easily maintained in the large holding tanks at this laboratory, where they are kept to help control growths of algae on the walls and floors of these tanks. Another is that they are known to mature sexually in captivity and have been occasionally observed to spawn naturally in these tanks. Finally, the observations of Randall (1961) indicate that the larvae are small enough (yolk-sac larvae 1.7 mm in total length) to be ingested by skipjack tuna larvae less than two weeks of age.

Methods

Specimens for these studies were adult manini maintained in captivity at the Kewalo Research Facility for long, undetermined periods of up to several years. Techniques were developed to identify the sexes from external characteristics (as described in the Results section). For each of two experiments, one male and two females were isolated in a circular experimental tank 4 ft (1.23 m) in diameter and 18 inches (45.7 cm) in depth. Because the males could be stripped of milt before being placed into the experimental tank, they were not treated with hormones. Females received varying dosages of human chorionic gonadotropin (HCG) alone, or HCG and powdered salmon pituitaries dissolved or suspended in 1.1% NaCl solution. Injection volumes were 0.1 or 0.2 ml, depending on dosage level. Treatments are summarized in Table 1. Each female was injected twice, the first time at 9:30 to 10:30 am and the second 24 hours later. A fine-meshed net was placed over the outflow from the experimental tank to detect any release of ova by the treated females. Specimens were 180 to 209 mm in fork length and 176 to 229 g in weight. The experimental tank received continuous flow of seawater and temperatures in the tank ranged from about 25 to 28 C.

At varying intervals following the second injection, as described in the Results section, females were tested for ovulation by application of stripping pressure to the abdomen. If ripe ova were produced, they were stripped into a glass bowl and fertilized by stripping milt from the male present in the tank. Fertilization was thus effected by the "dry method" and the eggs and milt gently stirred in the receptacle for 3 to 5 minutes. In both experiments 1 and 2, the eggs were placed in 3-liter beakers filled with filtered seawater and provided with aeration. In the second

experiment, most of the eggs were transferred to 16-liter plastic buckets filled with filtered seawater and aerated. Also in the second experiment, 1000 advanced embryos were transferred to a 100-liter culture tank provided with filtered seawater, aerated, and inoculated with 4 liters each of two cultured algae, Tetraselmis sp. and Isochrysis sp. After hatching of the larvae, cultured rotifers, Brachionus plicatilis were also introduced into the culture tank and these rapidly increased into a dense population by the third day posthatch. Starting on the third day posthatch, 40% (40 liters) of the water volume was replaced with fresh, filtered seawater. Daily additions of 4 liters of each of the cultured algae were also added to replenish consumption by the rotifers.

Results

In manini, sexes can be distinguished by examination of the ventral slit in which the anus, genital pore and urinary pore are located. In males this slit is narrower and the urogenital area often cannot be seen unless pressure is applied to the abdomen to produce slight protrusion of this area. The ventral slit is wider in females and the urogenital area can be seen more readily. Also, there is a transverse fold readily visible between the anus and the genital area of females, but not of males. As females approach spawning condition the genital area becomes swollen and expands the width of the ventral slit. Ripe males will yield milt in response to light to moderate stripping pressure, making them particularly easy to identify during the breeding season.

Responses of the females to hormone treatments are summarized in Table 1. Ovulation was induced in three of the four treated females, both fish of Experiment 1 and one of the two in Experiment 2. Subsequent dissection of the single unresponsive female indicated that its ovaries were immature,

containing only small ova up to about .06 to .07 mm in diameter. Combinations of HCG and salmon pituitaries or HCG alone were effective in stimulating ovulation. The greatest response was from the female treated with the highest dosage of HCG, used alone without salmon pituitaries (Female 2A).

None of the three responsive females released ova externally and ovulation was confirmed by manually stripping ova from each. In the first experiment the treated fish were left undisturbed following each injection in order to provide the opportunity for them to spawn with the male present in the tank. When this did not occur, both females were tested with stripping pressure applied 25 hours after the second injections. Ovulation was confirmed by the release of ripe ova from each. In the second experiment the females were tested with stripping pressure applied 4, 8, 10, and 12 hours following the second injections. One female, as previously mentioned, did not ovulate. The other female did not yield ova after 4 hours postinjection but released an estimated 49,500 after 8 hours and an estimated 33,250 after 10 hours postinjection. Only a small number of ova were released after 12 hours postinjection and this part of the experiment was terminated at that time.

Ova stripped from the responsive females in each experiment were fertilized with milt stripped from the male present in the experimental tank. With the ova from the first experiment, stripped from the two females about 25 hours following the second injections, there was no evidence of successful fertilization and no embryonic development observed. With the ova from the second experiment, initial fertilization rates were not determined but after 19 to 23 hours, about 23% of the ova stripped out after 8 hours and about 40% of the ova stripped out after 10 hours following the second injection were undergoing advanced embryonic development.

Table 1. Responses of female manini to two daily injections of human chorionic gonadotropin (HCG), or HCG and powdered salmon pituitaries (SP).

<u>Spec. No.</u>	<u>1st Injection</u>	<u>2nd Injection</u>	<u>Response</u>
<u>Experiment 1</u>			
1A	100 IU HCG	100 IU HCG + 1.0 mg SP	Estimated 16,000 ova stripped about 25 hours after second injection
1B	100 IU HCG	100 IU HCG + 1.0 mg SP	Estimated 1,700 ova stripped about 25 hours after second injection
<u>Experiment 2</u>			
2A	200 IU HCG	500 IU HCG	Estimated total of 83,000 ova stripped in two batches, 8 and 10 hours after second injection
2B	300 IU HCG	600 IU HCG + 20 mg SP	no ovulation, female with immature ovaries

Embryonic and early larval development followed the pattern and approximate temporal sequence described by Randall (1961). Ripe eggs were about .65 to .70 mm in diameter and those fertilized were slightly bouyant and floated in unagitated seawater. Nonviable eggs either sank or also floated. At incubation temperatures of about 24.5 to 28 C, the first cleavage divisions were evident by one hour after fertilization. The larvae hatched out during the second night. Times of hatching were not observed, but Randall (1961) reported that manini larvae hatched out about 26 hours after fertilization at incubation temperature of about 24 C. The number of larvae hatched out was estimated to be about 17,000 not including those in the culture tank.

The larvae in the two 16-liter plastic buckets were not fed. Their survival appeared very good until the third day, when large numbers appeared to be dying by midafternoon. Numbers of larvae were greatly reduced by the fourth day and few could be found on the fifth day after hatching.

The larvae in the 100-liter culture tank started feeding on the third day after hatching. Clumps of algal cells were clearly visible in their digestive tracts and they appeared healthy and active at this time. This same pattern continued through the fourth day posthatch, but numbers of larvae in the culture were considerably diminished by the morning of the fifth day. On the sixth day, the remaining larvae were obviously dying, no longer swimming actively but instead mostly drifting passively with currents induced by aeration of the tank. On the seventh day posthatch, live larvae could no longer be found. Larvae fed on algae from the third through the sixth day, but I could not see any rotifers in their digestive tracts despite the high densities of both adult and immature Brachionus in the culture tank.

Discussion

The results indicate that HCG used alone is an effective ovulating agent for manini. This is advantageous since HCG is readily available, easy to work with, and relatively inexpensive. The much greater response by female 2A than by either females 1A or 1B suggests that the higher dosages of HCG administered to the former were a more effective treatment. However, this is a tentative conclusion based on responses by only three specimens. Further experimentation was made impractical by the accidental deaths, associated with an electrical power failure, of 14 of the 24

adult specimens remaining after the second experiment. Since the treatment administered to female 2A was highly effective in producing viable, fertilizable ova, it was decided that the surviving adult specimens should be saved to produce manini larvae for the tuna larval rearing trials.

The complete infertility of the ova stripped from females 1A and 1B 25 hours following the second daily injection, and the difference in fertility between the two batches of ova stripped from female 2A indicate that viability of the eggs decreases rapidly following ovulation. With female 2A, it was apparent that large numbers of ova had been ovulated by 8 hours following the second injection. It is likely that many of the ova stripped out at this time had been ovulated more than an hour earlier. It also appeared that ovulation was still continuing when the female was stripped at 8 hours, and that those stripped out two hours later, at 10 hours postinjection, therefore contained a higher proportion of recently ovulated eggs. This could have produced the difference in fertility (23% vs. 40% of eggs producing advanced embryos).

Although the larvae which were fed lived for two to three days longer than those not offered any food, it is not known to what extent the ingestion of algae, but seemingly not of rotifers, actually contributed to the longer survival. Other factors, such as the higher densities of larvae in the buckets than in the culture tank, daily replacement of 40% of the water in the culture tank but no water replacement in the buckets, and the possible effect of the algae on water quality in the culture tank, may have contributed to the difference in survival time.

Of the 14 manini killed during the electrical power failure, 8 were females. Of these, three had immature ovaries with largest ova 0.10 to

0.12 mm in diameter. The other five females had maturing ovaries with largest ova measuring about 0.38 to 0.42 mm in diameter. The ovaries of the latter almost certainly represented the starting condition of the ovaries of the three females which did respond to hormone treatments. The ovaries of the single unresponsive female were similar to those of the three accidentally killed females with immature ovaries. Randall (1961) found that the largest ova in mature female manini caught in Hawaiian waters during their breeding season (early December to late July in his study) have modal diameters of 0.35 to 0.42 mm. He found larger ova only in running ripe females and concluded that ripening eggs increase rapidly in size just before spawning. The proportion of mature females found by Randall (46 out of 54 examined) and among the captive specimens in this study (8 of 12, including both those accidentally killed and the experimental specimens), indicate that females responsive to hormone-induced spawnings should be readily available during the breeding season in either wild or captive populations. The use of two or more females in a given spawning attempt should make it highly probable that at least one will be sufficiently developed to respond.

Conclusions and Recommendations

Manini appear to represent a very promising potential source of larval fish as food for larval tuna. Juveniles and adults are maintained very easily and in apparent good health in the large holding tanks at the Kewalo Research Facility. The captive adults develop mature gonads and occasionally spawn naturally in these tanks.

Results of the present study indicate that mature adults maintained in captivity can be easily induced to spawn with injections of HCG. This hormone preparation is easy to administer, readily available, and relatively inexpensive. Yolk sac larvae will be available on the third

morning (about 72 hours) following the initiation of hormone treatments. Without any care other than being maintained in sufficient volume of aerated seawater, the yolk sac larvae and early prolarvae will remain alive and be available as food until the third day.

A recommended procedure and schedule for producing manini larvae for feeding to skipjack tuna larvae is presented in Appendix 1. The schedule assumes that skipjack tuna larvae are probably able to start feeding on fish larvae of this size by about their 8th to 10th day after hatching (T. Kazama and S. Hendrix, National Marine Fisheries Service, Honolulu Laboratory, pers. comm.)

Literature Cited

Randall, J. E. 1961. A contribution to the biology of the convict surgeonfish of the Hawaiian Islands, Acanthurus triostegus sandvicensis. Pacific Sci., 15: 215-272.

Appendix 1. Suggested procedure and schedule for producing manini larvae as food for larvae of skipjack tuna larvae.

skipjack larvae, posthatch day	Manini			
5	start sequence 1*			
6				
7		start sequence 2		
8	larvae available			
9	"		start sequence 3	
10	"	larvae available		
11		"		start sequence 4
12		"	larvae available	
13			"	
14			"	larvae available
15				"
16				"

* Each manini sequence with the following schedule:

first day: 9:00 to 9:30 am, inject each of two or more females with 200 IU HCG, intramuscular, in 0.1 ml saline solution (200 IU/0.1 ml)

second day: 9:00 to 9:30 am, inject each female with 500 IU HCG in 0.25 ml (same preparation as previous day, kept refrigerated)

starting at 3:00 pm (six hours postinjection) and repeating at one or two hour intervals, attempt to strip ova from each female. Fertilize and start incubation of each batch of eggs. Continue until ripe eggs no longer produced, or until lack of response evident.

third day: fertilized eggs in incubation

fourth day: early morning, yolk sac larvae available to initiate feeding to skipjack larvae



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SEAMOUNT FISHERY, FOREIGN VESSEL OBSERVER REPORT

KITAKAMI MARU (July 22-October 20, 1983)

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November 1983

[NOT FOR PUBLICATION]

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On July 22, 1983, I replaced Nathaniel T. Shippen as observer aboard the Japanese trawler Kitakami Maru (Table 1). We began fishing inside the Fishery Conservation Zone (FCZ) on July 23.

Table 1.--Vessel specifications and personnel, Kitakami Maru.

Vessel Statistics

Radio call sign:	JMLB
Permit number:	JA-83-0321-A
Length:	56.62 m
Gross tonnage:	549.86
Net tonnage:	215.92
Width:	9.2 m
Draft:	3.8 m
Engine type:	Diesel
Horsepower	1500
Hull number:	100765
Registration number:	F01-132
Company-owner:	Nippon Suisan Kaisha, Ltd.
Vessel type:	Independent stern trawler
Year commissioned:	1966
Home port:	Tobata, Kita-Kyushu, Japan

Personnel

Captain	Kaname Taketsugu
Number of officers:	8
Number of crew:	19
Processing:	15
Total ship complement:	27
Experience in seamount fishery:	None

Trawl Gear

See Figure 1 for dimensions. The net was modified by replacing two of the center bobbins opposite the cod end with two large cylinder-shaped bobbins composed of hard rubber. This reduced "hangups" by allowing the net to "bounce over small rocks and ledges.

Area of Operation

1. Outside of the U.S. Fishery Conservation Zone (FCZ).

See text.

Type of Vessel Independent stern trawler

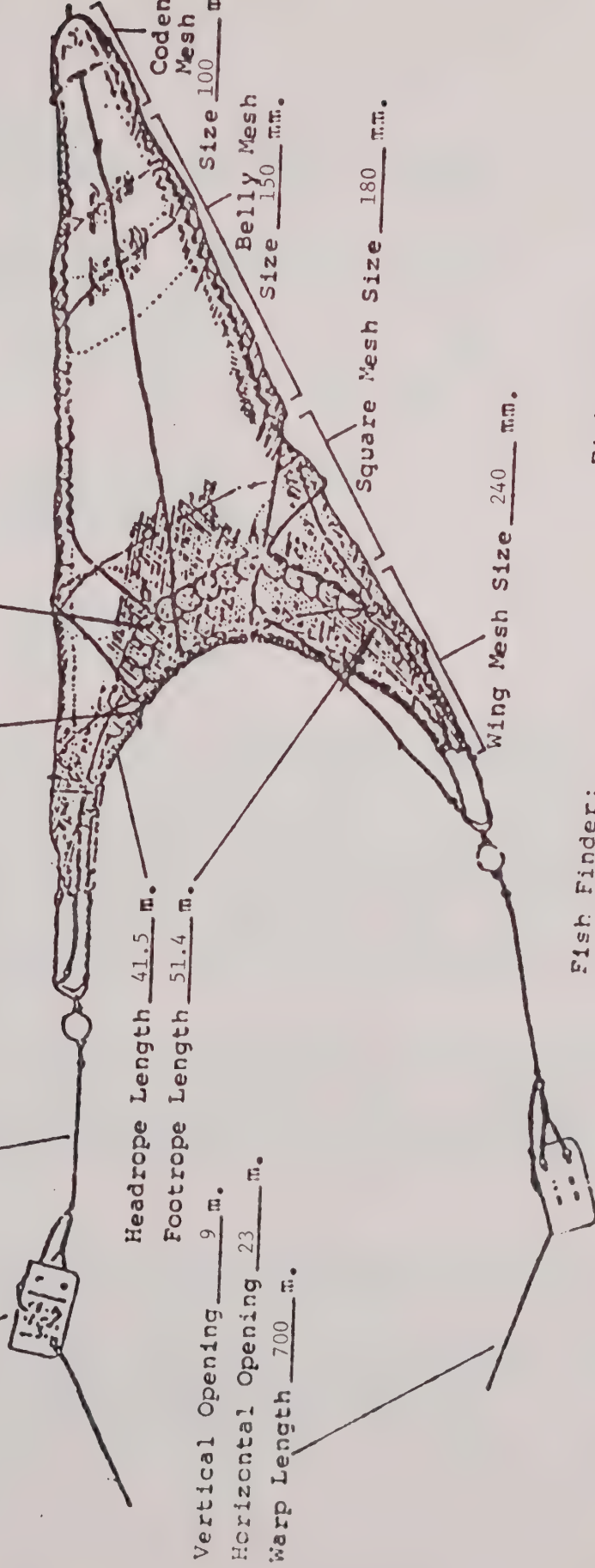
Observation Period July 22-October 20, 1983

Trawl Doors: Shape Rectangular
Type Steel
Dimensions 1.84 m. x 2.76 m.
Weight 1,758 kg.

Dandyline Length 130 m.

Floats: Number 23
Size 36 cm. diameter
Material Plastic
Shape Spherical

Bobbing: Number 23
Size 53 cm. diameter
Material 12 steel, 9 rubber
Shape Spherical



Headrope Length 41.5 m.

Footrope Length 51.4 m.

Vertical Opening 9 m.

Horizontal Opening 23 m.

Warp Length 700 m.

Fish Finder:

Name Kaijo Denki
Model Number Wide size
Frequency 24,75,200 Hz.
Paper Type Wet xx Dry
Speed of Advance 3 ft./min.

Fish Finder:

Name Japan Radio Corp.
Model Number NJA-330
Frequency 28,75,200 Hz.
Paper Type Wet xx Dry
Speed of Advance 3 ft./min.

Net Recorder:

Name Furuno
Model Number FNR 100
Frequency 50 Hz. (to ship)
180 Hz. (to bottom)

2. FCZ.

- a. Southeast Hancock Seamount (J Bank), lat. 29°43'-49'N, long. 179°02'-06'E
- b. Northwest Hancock Seamount (C Bank), lat. 30°15'-16'N, long. 178°42'-44'E
- c. K Bank, lat. 29°40'N, long. 179°20'E

TRAWL RESULTS

Target Species

Common names: Pelagic armorhead, boarfish
 Japanese name: Kusakari tsubodai
 Scientific name: Pentaceros richardsoni
 Species code: 080

Common name: Alfonsin
 Japanese name: Kinmedai
 Scientific name: Beryx splendens
 Species code: 081

After the first couple of trawls at Northwest Hancock Seamount it became apparent that the catch rate had dropped significantly from the previous fishing period from June 9 to July 21.¹ During the first 4 days of fishing at Hancock, the total catch averaged less than 2 metric tons (MT) per day. Because of this low catch rate most of the time was spent fishing outside of the FCZ. I remained as an observer during this entire period from July 22, until we returned to Japan on October 8. Out of a total of 70 fishing days, 15 were spent inside of the FCZ. We reentered the FCZ on two additional occasions; from August 14 to 20 and from September 14 to 17. Average daily catch rate during these periods dropped to 1.5 and 1.0 MT, respectively.

At Southeast Hancock, over a period of 9 fishing days and 44 trawling stations, average time per haul was 124 min.² There were 23 trawls of 500 kg or less total catch with 11 trawls producing 0 catch. The remaining 6 days at Northwest Hancock yielded 29 trawls at an average of 119 min per haul. All but two trawls at Northwest Hancock were 500 kg or less and 17 trawls here produced 0 catch. A single trawl at K Bank lasted 10 min and generated zero catch.

¹See Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812, Admin. Rep. H-83-18, 7 p.

²Time per haul is the actual time the net was in the water and may include several passes over the seamount plus ship turn-around time. See Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812, Admin. Rep. H-80-15, 13 p.

A total of 21,050 kg were caught inside the FCZ (Table 2). Armorhead accounted for 11,370 kg or 54%, while alfonsin comprised 1,225 kg (6%). Other species comprised the remaining 40% with a total weight of 8,455 kg (Table 3).

Table 2.--Catch per unit effort by area and species inside Fishery Conservation Zone.

	Southeast Hancock	Northwest Hancock	K Bank
No. hauls	44	29	1
Total minutes (trawl in water)	5,320	3,450	10
Armorhead			
Total catch (kg)	9,245	2,125	0
Kilogram/minute	1.74	0.62	
Alfonsin			
Total catch (kg)	150	1,075	0
Kilogram/minute	0.028	0.31	
Other species			
Total catch (kg)	6,555	1,900	0
Kilogram/minute	1.23	0.55	
All species			
Total catch (kg)	15,950	5,100	0
Kilogram/minute	3.00	1.48	

Table 3.--Trawl catches (in kilograms) by species in the Fishery Conservation Zone.

Species	Catch in kilograms
<u>Pentaceros richardsoni</u>	11,370
<u>Beryx splendens</u>	1,225
Others	8,455
<u>B. decadactylus</u>	
<u>Zenopsis nebulosus</u>	
<u>Emmelichthys struhsakeri</u>	
<u>Antigonia</u> sp.	
<u>Polymixia japonicus</u>	
<u>Macrorhamphosus</u> spp.	
<u>Priacanthus</u> sp.	
<u>Pseudanthias kelloggi</u>	
<u>Grammatonotus laysanus</u>	
<u>Hyperoglyphe japonica</u>	
Moridae	
Myctophidae	
Sternoptychidae	
Paralepididae	
<u>Ruvettus pretiosus</u>	
<u>Promethichthys prometheus</u>	
<u>Epinnula magistralis</u>	
<u>Arionmma lurida</u>	
<u>Setarches guentheri</u>	
<u>Peristedion engyceros</u>	
<u>Chascanopsetta prorigera</u>	
<u>Parabothus coarctatus</u>	
Echeneidae	
Tetraodontidae	
<u>Halieutaea retifera</u>	
Pentaceridae	
<u>Decapterus tabl</u>	
<u>Scomber japonicus</u>	
<u>Holicolenus</u> sp.	
<u>Hexanchus griseus</u>	
<u>Prionace glauca</u>	
Carcharhinidae	
Squalidae	
<u>Etmopterus villosus</u>	
<u>Isistius brasiliensis</u>	
<u>Echinorhinus cookei</u>	
Urolophidae	
Dasyatidae	
Squids	

SAMPLING RESULTS

1. Pelagic armorhead, Pentaceros richardsoni

Morphology: As in previous cruises pelagic armorhead was divided into three separate and distinct body types--fat, lean, and intermediate--based on difference in coloration, fat content, and body shape. It should be noted that there is often very close distinction between lean and intermediate types. Therefore, morphological data may vary between these two types depending on the interpretation of each observer as to what category an individual fish belongs in (Table 4).

Table 4.--Observations on armorhead, Pentaceros richardsoni.

a. Southeast Hancock Seamount

Lean type 92%

Number measured: 649

Sex ratio: Male 227 (54%)
Female 196 (46%)

Average length: 300 mm Range: 253-336
Average weight: 0.53 kg 0.29-0.75

Fat type 2%

Number measured: 10

Sex ratio: Male 3 (33%)
Female 6 (67%)

Average length: 318 mm Range: 303-355
Average weight: 0.91 kg 0.75-1.20

Intermediate type 6%

Number measured: 48

Sex ratio: Male 5 (16%)
Female 27 (84%)

Average length: 315 mm Range: 275-336
Average weight: 0.71 kg 0.55-0.82

b. Northwest Hancock Seamount

Lean type 77%

Number measured: 261

Sex ratio: Male 76 (64%)
 Female 43 (36%)

Average length: 304 mm Range: 265-334
 Average weight: 0.56 kg 0.32-0.75

Fat type 8%

Number measured: 20

Sex ratio: Male 12 (71%)
 Female 5 (29%)

Average length: 308 mm Range: 270-332
 Average weight: 0.84 kg 0.57-0.98

Intermediate type 15%

Number measured: 40

Sex ratio: Male 9 (26%)
 Female 25 (74%)

Average length: 313 mm Range: 276-343
 Average weight: 0.66 kg 0.48-0.92

2. Alfonsin, Beryx splendens

Morphology: Alfonsin was not sampled at Southeast Hancock owing to the low catch rate there. Reliable sampling results were only obtained at Northwest Hancock. Alfonsin here seemed to fall into two distinct size groups. The most prevalent type was the small (15-20 cm) size category. This type made up about 80% of the total catch. Large alfonsin (30-40 cm) made up the remainder of the catch and was occasionally found in sizable numbers relative to the other species caught. Intermediate size alfonsin seemed to be almost completely absent from the seamounts (Table 5).

Other commercial species:

Other species caught in significant quantities and utilized as product included Emmelichthys struhsakeri, Ariomma lurida, and Hyperoglyphe japonica. Emmelichthys struhsakeri was the most prevalent of the other species often comprising over 50% of the total catch in a single haul. Whole fish were placed in trays and frozen. Large H. japonica were usually headed, gutted, and frozen individually, while A. lurida was dressed and frozen in trays. Small quantities of Scomber japonicus and Decapterus tabl were caught and utilized by the galley. Zenopsis nebulosa was also caught in significant quantities but were seldom used as product. A total of about 17 sharks (3,200 kg) and 4 rays (600 kg) were caught inside the FCZ. These sharks and rays, in addition to all other incidental species caught, were not utilized by the vessel in any manner (Table 6).

Table 5.--Observations on alfonsins, Beryx splendens.

Northwest Hancock SeamountSmall type

Number measured: 75

Sex ratio: All immature

Average length:	166 mm	Range:	155-190
Average weight:	0.13 kg		0.10-0.21

Large type

Number measured: 50

Sex ratio:	Male	34 (68%)
	Female	16 (32%)

Average length:	329 mm	Range:	213-442
Average weight:	1.18 kg		0.29-2.50

Table 6.--Species products.

Pelagic armorhead

Frozen fish (headed and gutted)	4.9 MT
Fish meal and oil	0

Alfonsin

Frozen whole or headed and gutted	0.6 MT
Fish meal and oil	0

Other species

Frozen whole or headed and gutted	2.1 MT
Fish meal and oil	0

State of Maturation

During the sampling period from mid-July through September the vast majority of lean and intermediate armorhead were well into the developing stage of maturation. Many appeared sexually advanced indicating that spawning was imminent. Several ovaries were found in what seemed to be a spent condition, giving evidence that spawning may have recently taken place. Samples of each ovary were saved for later examination in the

laboratory. In the field they were grouped into five separate categories based on external physical characteristics. Later microscope examination will be necessary to confirm the field observations.

Generally, a greater percentage of the intermediate type armorhead were sexually mature than the other types. In addition nearly all of the fat types were immature and were practically the only immature ovaries encountered.

Alfonsins less than 20 cm were immature. The majority of those greater than 30 cm were ripe (hydrated) (Table 7).

Table 7.--State of maturation.

Armorhead	Lean		Intermediate			Fat		
Southeast Hancock Seamount								
Advanced:	73	39%	Advanced:	15	52%	Immature:	6	100%
Developing:	77	41%	Developing:	14	48%			
Immature:	3	2%						
Spent:	34	18%						
Northwest Hancock Seamount								
Advanced:	18	42%	Advanced:	12	44%	Immature:	3	60%
Developing:	20	46%	Developing:	14	52%	Developing:	1	20%
Spent:	5	12%	Spent:	1	4%	Ripe:	1	20%
<u>Alfonsin</u>								
Large type								
Ripe:	11	69%						
Developing:	2	12%						
Spent:	3	19%						

Activity Outside of the FCZ

Since the majority of time that I was on board was spent fishing outside of the FCZ included here is a brief description of the various seamounts northwest of Hancock that were exploited during this period. A total of 346 fishing stations were conducted outside of the FCZ.

G Bank

G Bank includes three separate bank areas: G-R plus G-B, and G-A to the northwest. G-R Bank located at lat. 34°56'N, long. 171°48'E was the only area where trawling operations were conducted within the G-Bank

series. The catch there was predominately small alfonsin (15-25 cm FL) often comprising as much as 95% of the total catch. Other species caught incidentally to alfonsin were Squalus blainvillei, Helicolenus sp., and very large Z. nebulosa. Armorhead was occasionally caught in extremely small quantities. Trawls at G-R Bank were conducted 24 h a day, with the best catches during daylight hours. A total of about 550-600 MT were caught over a period of 36 fishing days. Unfortunately, much of the alfonsin was too small to be used as product.

F Bank

Includes F-A, F-B, and F-C Banks. A total of 6 fishing days were spent at F-B Bank, which is located at lat. 32°15'N, long. 175°44'E. The first few trawls yielded catches of up to 20 MT of large (30 cm and up) alfonsin. However, the catch rate dropped off quickly within the next couple of days and very few armorhead were caught here. Judging from the fathometer tracings, the bottom appeared to be very rough with a depth between 400 and 450 m. Although the total bank area was fairly large, only about one-fourth of this area was trawlable. Accordingly, there was a lot of net hangups here. Total catch was about 75 MT, nearly all alfonsin. A few trawls were attempted at F-A and F-C Bank over 2 fishing days. These regularly resulted in severe net hangups and zero catch.

E Bank

Seven fishing days were spent trawling at E Bank, located at lat. 31°01'N, long. 175°53'E. Approximately 20 MT comprised of mostly small alfonsin and Z. nebulosa were caught here. With the exception of one 4 MT trawl, very few armorhead were taken.

D Bank

A total of 5 fishing days were spent at D Bank located at lat. 30°21'N, long. 178°26'E, just outside of the FCZ. Only about 1.0 MT was caught, largely due to the small trawlable area and rough bottom which produced many net hangups. Single trawls were usually less than 100 kg and were comprised of Z. nebulosa with a few armorhead.

ITINERARY

July 13	- Departed Honolulu
July 14	- Arrived Tokyo, Japan
July 16	- Departed Tokyo via cargo vessel <u>Bering Maru</u>
July 22	- Arrived fishing grounds; transferred to <u>Kitakami Maru</u>
July 23	- Entered FCZ; began sampling
September 17	- Ceased fishing in FCZ
September 28	- Transit to Tobata, Japan
October 8	- Arrived Tobata, Japan
October 20	- Arrived Honolulu

RECORDS

The following records were kept:

Scientists log
Daily trawl haul form
Species composition from basket samples
Size-frequency log

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ANNOTATED BIBLIOGRAPHY OF SELECTED PUBLISHED AND UNPUBLISHED WORKS
ON BILLFISH, MAHIMAH, WAHOO, AND SHARKS

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INTRODUCTION

Since 1976, when the Western Pacific Regional Fishery Management Council (Council) first began developing a fishery management plan for billfish and assorted large pelagic species taken by longline gear in the U.S. Fishery Conservation Zone around Hawaii and other U.S. possessions in the Pacific, a number of studies have been undertaken by the Southwest Fisheries Center, Honolulu Laboratory (SWFC) in support of the Council. The scope of the fishery management plan has since changed. Other species, mahimahi, wahoo, and sharks, have been included, dropped, and then reintroduced. Tuna longline gear is now regarded as becoming less important and gill nets, purse seine, deep-sea handline (ika-shibi), and other gear are becoming progressively more important. As a consequence, the Council has asked the SWFC to provide a summary of studies carried out by the SWFC that could be used to improve the current version of the draft fishery management plan.

The purpose of this paper is to provide sources of information on billfish, mahimahi, wahoo, and sharks to support the development of a final fishery management plan for these large pelagic species by the Council and its associated bodies.

This bibliography deals with documents authored by the SWFC staff or prepared by others for activities sponsored by the SWFC. Abstracts of references marked with an asterisk (*) were reproduced in total from the original. All other abstracts were condensed or excerpted.

Sources include formal publications, Special Scientific Reports--Fisheries (SSRF), and Administrative Reports.

Research conducted by SWFC has focused on areas other than mahimahi, wahoo, and sharks; therefore, there are only a limited amount of publications in this area.

SPECIES IDENTIFICATION

de Sylva, D. P., and S. Ueyanagi.

1974. Comparative development of Atlantic and Mediterranean billfishes (Istiophoridae). (Abstr.) In R. S. Shomura, and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 79. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Fierstine, H. L.

1974. The paleontology of billfish--The state of the art. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 34-44. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

*The major osteological features are described for living billfishes. All billfish remains are reviewed critically and some questionable forms are placed in Xiphiodei Incertae Sedis (uncertain status). The remaining xiphioids are placed into three families: Istiophoridae, Xiphiidae, and Xiphioidrhynchidae. A new undescribed xiphiid from Mississippi shows that the billfish lineages must have diverged prior to the Eocene. Areas of research are suggested that will help place the paleontological studies on a more secure foundation.

Nakamura, I.

1974. Some aspects of the systematics and distribution of billfishes. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 45-53. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Key, with figures, is presented which includes 2 families, 4 genera, and 11 species. The worldwide distribution of billfishes is given; distributions are based primarily on data from the Japanese longline catch for 1964-69.

Richards, W. J.

1974. Evaluation of identification methods for young billfishes. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 62-72. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Most of the papers published from 1831 to date which deal with the identification of young billfishes (Families Xiphiidae and Istiophoridae) are reviewed. The present knowledge of the identification of adults is compared with the identification of young and problem areas are defined. Suggestions are made to resolve the problems encountered with the identification of the young stages (egg, larvae, and juveniles).

Robins, C. R.

1974. The validity and status of the roundscale spearfish, Tetrapturus georgei. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 54-61. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

A fourth Atlantic species of the istiophorid genus Tetrapturus was discovered in 1961 among commercial catches landed in Sicily, Portugal, and Spain. The species is described in detail.

Ueyanagi, S.

1974. On an additional diagnostic character for the identification of billfish larvae with some notes on the variations in pigmentation. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 73-78. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

The identification of billfish larvae has depended on such characteristics as the shape of the pectoral fin, pigmentation of the branchiostegal membrane, pigmentation of the lower jaw membrane, and head profile. Recent studies have resulted in additional diagnostic characters which differentiate between the striped marlin and blue marlin under 7 mm.

LIFE HISTORY

Beckett, J. S.

1974. Biology of swordfish, Xiphias gladius L., in the northwest Atlantic Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 103-106. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

The present knowledge of the biology of swordfish in the northwest Atlantic Ocean is summarized.

de Sylva, D. P.

1974. Life history of the Atlantic blue marlin, Makaira nigricans, with special reference to Jamaican waters. (Abstr.) In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 80. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Eldridge, M. B., and P. G. Wares.

1974. Some biological observations of billfish taken in the eastern Pacific, 1967-1970. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 89-101. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

From 1967 through 1970 sport-caught billfishes were sampled at Mazatlan, Sinaloa; and Buena Vista, Baja California, and at San Diego, California. Lengths, weights, morphometrics, meristics, and gonad data were collected on a total of 2,056 striped marlin, 821 sailfish, 61 blue marlin, and 1 black marlin. This paper presents information on reproduction, average length

and condition factor, food habits for 1970, and notes on parasites.

Hanamoto, E.

1974. Fishery-oceanographic studies of striped marlin, Tetrapturus audax, in waters off Baja California. 1. Fishing conditions in relation to the thermocline. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 302-308. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

In this report, the author analyzed fishing conditions for striped marlin in waters off Baja California in relation to the thermocline.

Iversen, R. T. B., and R. B. Kelley.

1974. Occurrence, morphology, and parasitism of gastric ulcers in blue marlin, Makaira nigricans, and black marlin, Makaira indica, from Hawaii. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 149-153. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Gastric ulcers were found in 10 of 14 blue marlin, Makaira nigricans, and 2 of 3 black marlin, M. indica, examined from 1967 to 1969 at the Hawaiian International Billfish Tournament. Parasitic nematodes were found imbedded in the base of ulcers in one blue marlin and two black marlins.

Jolley, J. W., Jr.

1974. On the biology of Florida east coast Atlantic sailfish (Istiophorus platypterus). In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 81-88. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Attempts are being made to estimate sailfish age using concentric rings in dorsal fin spines. If successful, growth rates will be determined for each sex and age of initial maturity described.

Lenarz, W. H., and E. L. Nakamura.

1974. Analysis of length and weight data on three species of billfish from the western Atlantic Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 121-125. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

*Estimates of parameters of relations among weight, girth, total length, fork length, trunk length, and caudal spread were made for blue marlin, white marlin, and sailfish captured in the western Atlantic.

Markle, G. E.

1974. Distribution of larval swordfish in the northwest Atlantic Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 252-260. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Surface plankton collections, mostly with neuston nets towed at 4-5 knots, during eight cruises (1965-72) yielded 119 swordfish larvae, 6-110 mm total length.

Mather, C. O.

1974. Scientific billfish investigation: present and future; Australia, New Zealand, Africa. (Abstr.) In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 102. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Mather, F. J., III, J. M. Mason, Jr., and H. L. Clark.

1974. Migrations of white marlin and blue marlin in the western North Atlantic Ocean--tagging results since May 1970. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 211-225. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Migrations of white marlin, Tetrapturus albidus Poey, and blue marlin, Makaira nigricans Lacépède, in the western North Atlantic Ocean are discussed in terms of tag returns obtained since the completion of data collection for the paper by Mather et al. (1972) in May 1970. [Mather, F. J., III, A. C. Jones, and G. L. Beardsley, Jr. 1972. Migration and distribution of white marlin and blue marlin in the Atlantic Ocean. Fish. Bull., U.S. 70:283-298.]

Mather, F. J., III, D. C. Tabb, J. M. Mason, Jr., and H. L. Clark.

1974. Results of sailfish tagging in western North Atlantic Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 194-210. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Migrations of sailfish, Istiophorus platypterus (Shaw and Nodder), in the western North Atlantic Ocean are discussed on the basis of results of three cooperative tagging programs.

Matsumoto, W. M., and T. K. Kazama.

1974. Occurrence of young billfishes in the central Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 238-251. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Plankton and other net-caught samples collected on cruises of the National Marine Fisheries Service, Honolulu Laboratory vessels in Hawaiian and central Pacific equatorial waters were examined for billfish larvae and juveniles. Species recognized were: blue marlin, Makaira nigricans; shortbill spearfish, Tetrapturus angustirostris; sailfish, Istiophorus platypterus; swordfish, Xiphias gladius.

Nishikawa, Y., and S. Ueyanagi.

1974. The distribution of the larvae of swordfish, Xiphias gladius, in the Indian and Pacific Oceans. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 261-264. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

The distribution of larval swordfish, Xiphias gladius, was determined on the basis of 325 specimens collected from Japanese research vessels operating in the Indian and Pacific Oceans. These larvae, ranging from 3 to 160 mm in total length, were caught by larval-net tows and by dip netting.

Penrith, M. J., and D. L. Cram.

1974. The Cape of Good Hope: A hidden barrier to billfishes. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 175-187. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Since 1838 there have been isolated reports of billfishes from the southern tip of Africa, but only during the years 1961-64, when a number of Cape Town based boats fished commercially for tuna using longline, were billfishes found to occur in considerable numbers.

Robins, C. R.

1974. Summer concentration of white marlin, Tetrapturus albidus, west of the Strait of Gibraltar. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 164-174. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Examination of fish catches landed in August 1961 at various parts in southern Portugal and the adjacent coast of Spain demonstrated that the white marlin, Tetrapturus albidus, concentrated in these waters during this month.

Royce, W. F.

1957. Observations on the spearfish of the central Pacific. U.S. Fish Wildl. Serv., Fish. Bull. 57:1-554.

The taxonomy, distribution, size, food, and spawning habits of spearfish are considered. Observations on several hundred spearfishes caught in the central equatorial Pacific and in the Hawaiian fishery are presented, together with an extensive review of Japanese and other literature. Species recognized are: swordfish, Xiphias gladius; shortbill spearfish, Tetrapturus angustirostris; sailfish, Istiophorus orientalis; black marlin, Istiompax marlina; striped marlin, Makaira audax; and Pacific blue marlin, Makaira ampla.

Scott, W. B., and S. N. Tibbo.

1974. Food and feeding habits of swordfish, Xiphias gladius Linnaeus, in the northwest Atlantic Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 138-141. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Food and feeding habits of swordfish were studied by examining stomachs of 141 individuals captured from July to October 1971 between the Grand Bank and the southeast part of Georges Bank in the Northwest Atlantic Ocean.

Skillman, R. A., and M. Y. Y. Yong.

1974. Length-weight relationships for six species of billfishes in the central Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 126-137. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

The weight-length relationship for six species of billfishes in the central Pacific Ocean were developed. Species recognized were: blue marlin, Makaira nigricans; sailfish, Istiophorus platypterus; black marlin, M. indica; shortnose spearfish, Tetrapturus angustirostris; striped marlin, T. audax; and swordfish, Xiphias gladius.

Skillman, R. A., and M. Y. Y. Yong.

1976. Von Bertalanffy growth curves for striped marlin, Tetrapturus audax, and blue marlin, Makaira nigricans, in the North Pacific Ocean. Fish. Bull., U.S. 74:553-566.

The growth of striped marlin and blue marlin was described by fitting von Bertalanffy growth curves to the progression of age-groups, by quarters, in the Hawaiian longline fishery from 1960 to 1970.

Squire, J. L., Jr.

1974. Catch distribution and related sea surface temperature for striped marlin (Tetrapturus audax) caught off San Diego, California. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 188-193. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Records for 4,535 striped marlin landed at San Diego, California and sea surface temperature data were examined for the period 1963 through 1970 to determine time-space distribution of striped marlin and the relationship of catch and sea surface temperature. Sea surface temperature conditions relative to increased catches were also compared.

1974. Migration patterns of Istiophoridae in the Pacific Ocean as determined by cooperative tagging programs. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 226-237. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

During 1954-71, 15,540 billfish were tagged. Records show 9,849 striped marlin, Tetrapturus audax; 4,821 sailfish, Istiophorus platypterus; 622 black marlin, Makaira indica; and 248 blue marlin, M. nigricans were tagged during this period.

Strasburg, D. W.

1969. Billfishes of the central Pacific Ocean. U.S. Fish Wildl. Serv., Circ. 311, 11 p.

Information on diet, sex ratio, sexual dimorphism, seasonal occurrence, spawning, early life history and growth, migrations, and length-weight relations are discussed. Species discussed were blue marlin, Makaira nigricans; black marlin, M. indica; striped marlin, Tetrapturus audax; shortbill spearfish, T. angustirostris; Pacific sailfish, Istiophorus orientalis; and broadbill swordfish, Xiphias gladius.

Strasburg, D. W.

1970. A report on the billfishes of the central Pacific Ocean. Bull. Mar. Sci. 20:575-604.

Interest in the 11 species of billfishes (blue marlin, Makaira nigricans; black marlin, M. indica; striped marlin, Tetrapturus audax; white marlin, T. albidus; shortbill spearfish, T. angustirostris; Mediterranean spearfish, T. belone; longbill spearfish, T. pfluegeri; Atlantic sailfish, Istiophorus americanus; Pacific sailfish, I. orientalis; Indian sailfish, I. gladius; and broadbill swordfish, Xiphias gladius) has steadily mounted since World War II, and, as they have come under increasing fishing pressure, arguments have arisen concerning the effects of fishing on their stocks. As large predators, the billfishes are difficult to study; our knowledge is largely restricted to catch statistics, anatomy, diet, and development of their young.

Uchiyama, J. H., and R. S. Shomura.

1974. Maturation and fecundity of swordfish, Xiphias gladius, from Hawaiian waters. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 142-148. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Sixteen swordfish, Xiphias gladius, ovaries ranging in weight from 39 to 20,000 g were examined. Fish size ranged from 47 to 246 kg.

Wares, P. G., and G. T. Sakagawa.

1974. Some morphometrics of billfishes from the eastern Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 107-120. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Length-weight and morphometric data collected over 4 years (1967-70) from sport fisheries at three eastern Pacific locations are presented for striped marlin, Tetrapturus audax; sailfish, Istiophorus platypterus; and blue marlin, Makaira nigricans. The data were gathered from San Diego, California (U.S.A.), Buena

Vista, Baja California, Sur (Mexico), and Mazatlan, Sinaloa (Mexico).

Yuen, H. S. H.

1980. A study of live and dead billfishes caught on longline gear. Southwest Fish. Cent. Admin. Rep. H-80-12, 10 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

This paper investigates some of the factors which may be related to billfish (blue marlin, Makaira nigricans; black marlin, M. indica; striped marlin, Tetrapturus audax; shortbill spearfish, T. angustirostris; and sailfish, Istiophorus platypterus) being alive or dead at the time of boating.

Yuen, H. S. H., A. E. Dizon, and J. H. Uchiyama.

1974. Notes on the tracking of the Pacific blue marlin, Makaira nigricans. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 265-268. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

In July of 1971 and 1972 five Pacific blue marlin, Makaira nigricans, were tagged with temperature sensing, ultrasonic transmitters off the west coast of Hawaii.

FISHERY

Bartoo, N. W., and S. Ueyanagi (rapporteurs).

1980. Striped marlin, Tetrapturus audax. In R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop - Pacific Resources, p. 20-29. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-5.

Review of fisheries data.

de Sylva, D. P.

1974. A review of the world sport fishery for billfishes (Istiophoridae and Xiphiidae). In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 12-33. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

There is evidence that commercial fishing in the eastern Pacific is affecting the sport catches of sailfish, Istiophorus platypterus, and striped marlin, Tetrapturus angustirostris. Based on commercial catch data, the mean size of sailfish and striped marlin and their hooking rate have decreased. Sport fishing for billfishes poses special problems because of the complexity,

expense, expertise required, and lack of basic information on these fisheries and the fishermen. Possible solutions to these are discussed.

Hida, T. S., and R. A. Skillman.

1983. A note on the commercial fisheries in Hawaii. Southwest Fish. Cent. Admin. Rep. H-82-20 (Rev.), 9 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

*Commercial fish landings in the State of Hawaii for the 11 most important species are given for 1960, 1970, and 1980. Presented also are brief descriptions of the major fisheries accounting for these landings.

Huang, H. C.

1974. Billfish fishery of Taiwan. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 332-335. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

*Billfish landings made by Taiwan fishing vessels from 1962 to 1971 are analyzed and described briefly.

Ikehara, W. N.

1981. A survey of the ika-shibi fishery in the State of Hawaii, 1980. Southwest Fish. Cent. Admin. Rep. H-82-4C, 12 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

The rapidly growing ika-shibi, or night handline, fishery for tunas in Hawaii is described. Means of data collection, landings, and problems in present methods of data collection and burnt tuna are discussed.

Joseph, J., W. L. Klawe, and C. J. Orange.

1974. A review of the longline fishery for billfishes in the eastern Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 309-331. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Catch and effort statistics from the Japanese longline fishery are used to examine the quarterly distribution of each of the six species of billfishes taken in the eastern Pacific Ocean east of long. 130°W.

Nakamura, E. L., and L. R. Rivas.

1974. An analysis of the sport fishery for billfishes in the northeastern Gulf of Mexico during 1971. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review

and Contributed Papers, p. 269-289. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Data were obtained on the sport fishery for billfishes off South Pass, Louisiana and off northwest Florida in 1971. These data included: dates and times of raises; hookups, and catches by species; locations of raises; areas fished; baits used; water color; surface conditions; and boat characteristics.

Otsu, T.

1954. Analysis of the Hawaiian long-line fishery, 1948-52. Commer. Fish. Rev. 16(9):1-17. (Sep. 376.)

This report gives information on increase in tuna landings, change in the composition of catch, seasonality for tunas and marlins, and catch per unit of effort.

Sakagawa, G. T., and R. R. Bell (rapporteurs).

1980. Swordfish, Xiphias gladius. In R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop - Pacific Resources, p. 40-50. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-5.

Review of fisheries data.

Squire, J. L., Jr.

1974. Angler catch rates of billfishes in the Pacific Ocean. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed papers, p. 290-295. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

In 1969, 1970, and 1971 marine game fish anglers participating in a fish tagging program were asked questions concerning catches they made. From the 17,876 angler days reported, the catch consisted of 10,234 billfishes.

Squire, J. L., and Z. Suzuki (rapporteurs).

1980. Sailfish, Istiophorus platypterus, and shortbill spearfish, Tetrapturus angustirostris. In R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop - Pacific Resources, p. 30-39. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-5.

Review of fishery data.

Tibbo, S. N., and A. Sreedharan.

1974. The Canadian swordfish fishery. (Abstr.) In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish

Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 296. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Ueyanagi, S.

1974. A review of the world commercial fisheries for billfishes.

In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 1-11. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

This report reviews the commercial fisheries for billfishes. It also discusses the value and utilization of billfishes in Japan, and describes how billfishes have gained status as a quality fish, commanding prices comparable to the tunas. Expansion of the longline fishery is described.

U.S. National Marine Fisheries Service.

1982. The 1976-78 studies of the Kailua-Kona, Hawaii billfish fishery. Part I, Commercial/recreational component. Southwest Fish. Cent. Admin. Rep. H-82-3, 22 p. + append. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

This report contains information on both commercial and recreational fishers residing in Kailua-Kona. People were interviewed only if they fished for certain species--marlin, ono, ahi, aku, and mahimahi.

Wetherall, J. A., and R.-T. Yang.

1980. Black marlin, Makaira indica. In R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop - Pacific Resources, p. 51-57. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-5.

Review of fishery data.

Yong, M. Y. Y., and J. A. Wetherall.

1980. Estimates of the catch and effort by foreign tuna longliners and baitboats in the fishery conservation zone of the central and western Pacific, 1965-77. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-2, 103 p.

Estimates of catch and effort by Japanese and Taiwan longliners in central and western Pacific.

Yoshida, H. O.

1974. Landings of billfishes in the Hawaiian longline fishery. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 2. Review and Contributed Papers, p. 297-301. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

The landings of the longline fishery are dominated by the tunas. The catch of billfishes is composed of the striped marlin, Tetrapturus audax; blue marlin, Makaira nigricans; black marlin, M. indica; sailfish, Istiophorus platypterus; shortbill spearfish, T. angustirostris; and swordfish, Xiphias gladius.

Yuen, H. S. H.

1977. Overview of fisheries for billfishes in Hawaii. Southwest Fish. Cent. Admin. Rep. 19H, 1977, 14 p. + attach. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

This paper is a review of the catch statistics and the deductions that may be made from certain analyses of these statistics.

Yuen, H. S. H., and P. M. Miyake (rapporteurs).

1980. Blue marlin, Makaira nigricans. In R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop - Pacific Resources, p. 13-19. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-5.

Review of fishery data.

STOCK ASSESSMENT

Lovejoy, W. S.

1977. BFISH: A population dynamics and fishery management model. Southwest Fish. Cent. Admin. Rep. 12H, 1977, 62 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Billfish computer modeling for alternative fishery management schemes.

1981. BFISH revisited. [Report submitted to the Western Pacific Regional Fishery Management Council, Honolulu, in fulfillment of Contract No. WPC-00781.] 36 p.

Supplement to BFISH. A population dynamics and fishery management model.

Polovina, J. J., and N. T. Shippen.

1983. Estimates of the catch and effort by Japanese longliners and baitboats in the fishery conservation zone around the Mariana Archipelago. Southwest Fish. Cent. Admin. Rep. H-83-1, 42 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

This report presents historical Japanese tuna catch and effort data. Also analysis of magnitude, species composition, and general location of Japanese catches.

Wetherall, J. A., and M. Y. Y. Yong.

1977. An assessment of Pacific billfish stocks based on the generalized production model. Southwest Fish. Cent. Admin. Rep. 18H, 1977, 31 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Results of a preliminary assessment of Pacific billfish stocks are presented. The assessment is based on a standard production model analysis of Japanese tuna longline data.

ECONOMICS

Adams, M. F.

1978. Alternative estimates of net economic benefits for billfish-tuna recreational-commercial fishermen in Kailua-Kona, Hawaii. Southwest Fish. Cent. Admin. Rep. 18H, 1978, 10 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Economic estimates concerning recreational-commercial fishermen are presented.

Cooper, J. C., and M. F. Adams.

1978. Preliminary estimates of catch, sales, and revenue of game fish for the fishery conservation zone around the main Hawaiian Islands, by types of troll and longline vessels and by species, 1976. Southwest Fish. Cent. Admin. Rep. 24H, 1978, 10 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

This report estimates the catch, sales, and revenue generated by billfishes, tuna, and other game fishes in the Kailua-Kona area and in the entire State of Hawaii.

U.S. National Marine Fisheries Service.

1982. Preliminary results of a survey of wholesale fish dealers in Hawaii. Southwest Fish. Cent. Admin. Rep. H-82-14, 17 p. + append. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Sixteen firms out of 106 dealt with billfish. Billfish accounted for less than 34% of wholesale business for any of these firms.

HAWAIIAN INTERNATIONAL BILLFISH TOURNAMENT DATA

Naughton, J. J.

1973. Investigations of billfish biology at the Hawaiian International Billfish Tournament. Mar. Fish. Rev. 35(8):19-25.

This paper outlines the tournament and summarizes data collected from 1962 to 1972.

Yuen, H. S. H.

1974. Report of the 16th Hawaiian International Billfish Tournament, Kailua-Kona, Hawaii, July 13-20, 1974. Southwest Fish. Cent. Admin. Rep. 36H, 1974, 10 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Report of the biological and statistical aspects of the 16th Hawaiian International Billfish Tournament.

1975. To all billfishers. Southwest Fish. Cent. Admin. Rep. 17H, 1975, 20 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

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Report of the biological and statistical aspects of the 18th Hawaiian International Billfish Tournament.

1977. To all billfishers. Southwest Fish. Cent. Admin. Rep. 14H, 1977, 13 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Report of the biological and statistical aspects of the 19th Hawaiian International Billfish Tournament.

1978. To all billfishers. Southwest Fish. Cent. Admin. Rep. 22H, 1978, 12 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Report of the biological and statistical aspects of the 20th Hawaiian International Billfish Tournament.

1979. To all billfishers. Southwest Fish. Cent. Admin. Rep. H-79-22, 13 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Report of the biological and statistical aspects of the 21st Hawaiian International Billfish Tournament.

SPECIES SYNOPSIS

Beardsley, G. L., Jr., N. R. Merrett, and W. J. Richards.

1975. Synopsis of the biology of the sailfish, Istiophorus platypterus (Shaw and Nodder, 1791). In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 95-120. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history

de Sylva, D. P.

1975. Synopsis of biological data on the Mediterranean spearfish, Tetrapturus belone Rafinesque. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 121-131. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Kikawa, S.

1975. Synopsis on the biology of the shortbill spearfish, Tetrapturus angustirostris Tanaka, 1914 in the Indo-Pacific areas. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 39-54. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Mather, F. J., III, H. L. Clark, and J. M. Mason, Jr.

1975. Synopsis of the biology of the white marlin, Tetrapturus albidus Poey (1861). In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis p. 55-94. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Nakamura, I.

1975. Synopsis of the biology of the black marlin, Makaira indica (Cuvier), 1831. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 17-27. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Rivas, L. R.

1975. Synopsis of biological data on blue marlin, Makaira nigricans Lacépède, 1802. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 1-16. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Robins, C. R.

1975. Synopsis of biological data on the longbill spearfish, Tetrapturus pfluegeri Robins and de Sylva. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish

Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 28-38. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

Ueyanagi, S., and P. G. Wares.

1975. Synopsis of biological data on striped marlin, Tetrapturus audax (Philippi), 1887. In R. S. Shomura and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species Synopsis, p. 132-159. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-675.

Biology and life history.

MAHIMAH

B.T. and Associates.

1983. Recent trends in the Hawaii markets for mahimahi and ono. Southwest Fish. Cent. Admin. Rep. H-83-6C, 23 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

The rising price and demand for mahimahi and ono in Hawaii and comments on the factors which led to this growth are documented.

Hendrix, S. D.

1983. The early life history of mahimahi (Coryphaena hippurus and C. equiselis) and skipjack tuna (Katsuwonus pelamis): A report of the culture and growth of larval fish reared in the laboratory. Southwest Fish. Cent. Admin. Rep. H-83-2C, 40 p. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Studies of the growth, development, behavior, mortality, and condition of larval skipjack tuna and mahimahi reared in controlled laboratory condition are summarized.

Hida, T. S.

1973. Food of tunas and dolphins (Pisces: Scombridae and Coryphaenidae) with emphasis on the distribution and biology of their prey Stolephorus buccaneeri (Engraulidae). Fish. Bull., U.S. 71:135-143.

This paper presents results of the examination of stomach contents.

WAHOO

Iversen, E. S., and H. O. Yoshida.

1957. Notes on the biology of the wahoo in the Line Islands. Pac. Sci. 11:370-379.

Biological observations were made on wahoo, Acanthocybium solandri (Cuvier and Valenciennes), from the vicinity of the Line Islands during 1950 to 1956.

Matsumoto, W. M.

1967. Morphology and distribution of larval wahoo, Acanthocybium solandri (Cuvier), in the central Pacific Ocean. U.S. Fish. Wildl. Serv., Fish. Bull. 66:299-322.

Descriptions are presented of the early developmental stages of the wahoo.

SHARKS

Strasburg, D. W.

1957. Sharks of the central Pacific...Nuisance or resource? Pan Am. Fisherm. 11(9):6-7, 11-15.

Provides background information on sharks.

1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. U.S. Fish Wildl. Serv., Fish. Bull. 58: 335-361.

The biology of common sharks, migrations, and vertical distribution are discussed.

